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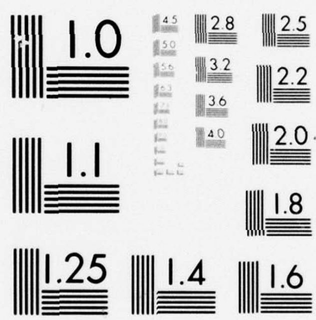

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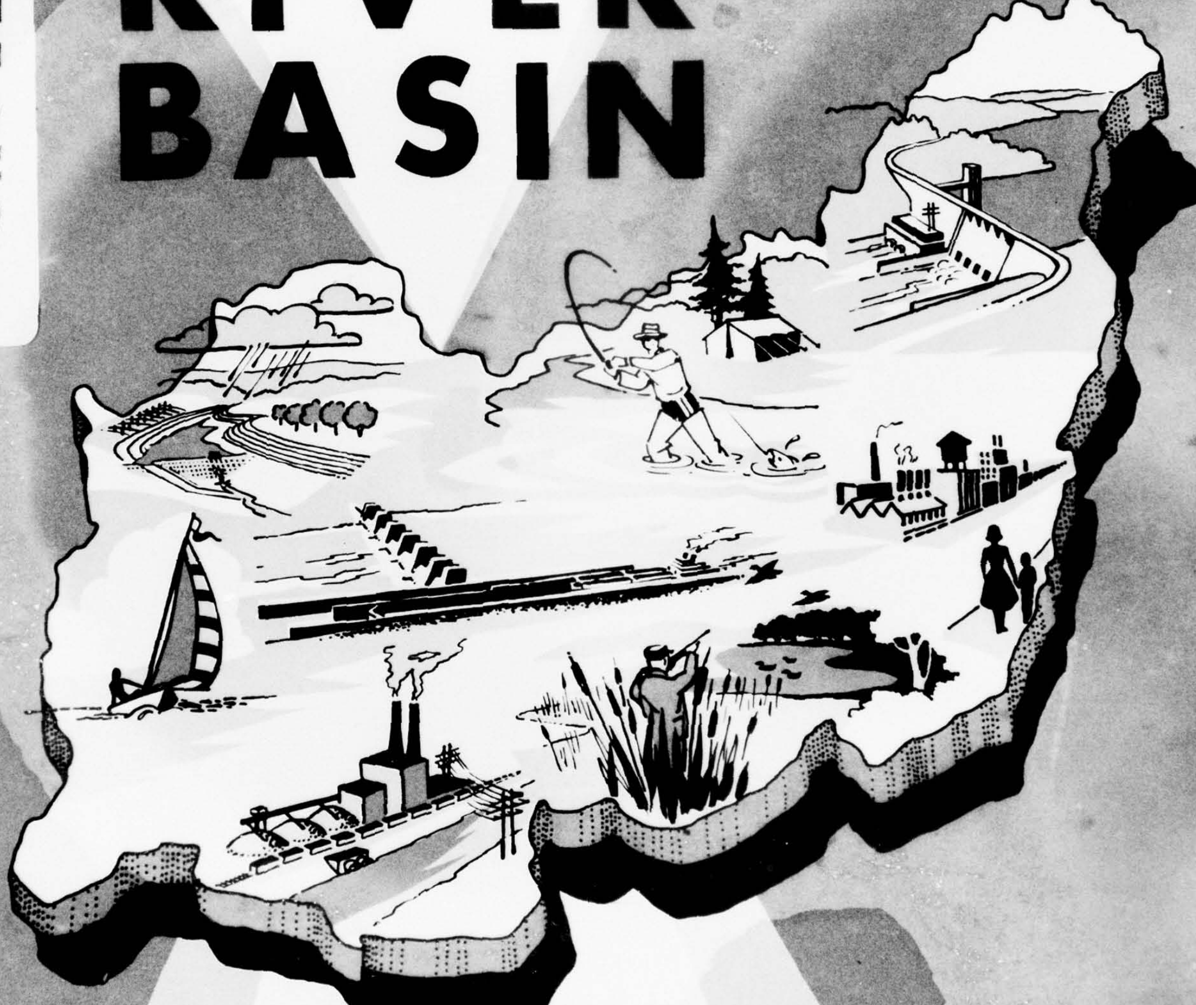
VOLUME XIII

OHIO RIVER BASIN



COMPREHENSIVE SURVEY

Appendix L

NAVIGATION

Prepared by U.S. Army Engineer Division, Ohio River

In cooperation with

the United States Departments of Agriculture, Commerce, Health, Education, and Welfare and the Interior

the Federal Power Commission

and participating States and Commonwealths

U.S. ARMY ENGINEER DIVISION, OHIO RIVER-CINCINNATI, OHIO

(1)

APPENDIX L: NAVIGATION.

(6) OHIO RIVER BASIN COMPREHENSIVE SURVEY

Volume XIII.

prepared by

U.S. ARMY ENGINEER DIVISION, OHIO RIVER
CORPS OF ENGINEERS
CINCINNATI, OHIO

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Agriculture, Commerce
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and the States or Commonwealths of
Illinois, Indiana
Kentucky, Maryland
New York, North Carolina
Ohio, Pennsylvania
Tennessee, Virginia
and West Virginia

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PREFACE

This report by the Corps of Engineers on water transportation is an integral part of the Ohio River Basin Comprehensive Survey authorized by Senate resolution adopted May 16, 1955, by the Committee on Public Works "to review the reports on the Ohio River published in House Document Numbered 306, Seventy-fourth Congress, First Session, House Committee on Flood Control Document Numbered 1, Seventy-fifth Congress, First Session, and related reports, with a view to determining whether any modification in the present comprehensive plan for flood control and other purposes in the Ohio River Basin is advisable at this time."

The basic objective of the survey has been to formulate a framework plan and development program which will serve as a broad guide to the best use, or combination of uses, of Ohio River Basin water and related land resources to meet forseeable short- and long-term needs. The report on the Ohio River Basin presents the first endeavor in the nationwide program of comprehensive basin studies of framework scope.

This appendix was prepared under the guidelines of the Water Resources Council and provides a broad-scaled evaluation of the demands for and problems of waterborne transport in the Ohio River Basin exclusive of the Tennessee River Valley. The study furnishes general appraisals of the probable nature, extent, and timing of measures for meeting future water transport demands without undertaking economic feasibility analyses and project formulation. Available data, reasoned approximations, general relations, and the judgement of experienced planners were the basis for selecting potential improvements as elements for the basin framework plan and development program.

A summary of the appendix is given in section I. Section II contains a review of the history of navigation in the Ohio River Basin and the present development of the waterways system. The demand for water transportation is analyzed in section III, which covers recent trends in the basin's waterborne commerce, projected gross demands for freight transport by water, the capability of the navigation projects in the 1965 program to meet future needs, and the remaining net demands to be satisfied by new resource developments. Section IV presents a discussion of present and anticipated problems associated with navigation as well as their potential solutions, ending with a recommended development program for meeting the future needs of water transport in the study area.

C O N T E N T S

C O N T E N T S - Continued

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SECTION I. SUMMARY

The development of a well-balanced, integrated transportation system in the Ohio River Basin generally has kept abreast of the needs. Extensive railroad, highway, and airway networks provide rapid and dependable freight and passenger service. Pipelines and canalized waterways provide low-cost movement of enormous amounts of bulk commodities. Large increases in waterway traffic, obsolete locks and dams, and the relatively short lengths of navigation pools have caused traffic congestion and delays. Currently, a program is underway to replace the outmoded and inadequate system on the Ohio River with a smaller number of higher dams, larger locks, and longer pools. Similar programs for several tributaries are in progress.

River navigation has been an important factor in the development of the basin and the westward expansion of the nation. Navigation improvements in the Ohio River began in 1824 as a result of an act of Congress which authorized removal of sandbars and snags. By 1830, a private stock company, with Federal participation, had built a canal with a three-flight lock around the dangerous Falls of the Ohio. In those days when transportation was difficult, the States and private companies provided an extensive network of improved tributaries and connecting man-made waterways. Federal canalization of the upper Ohio River for 6-foot navigation was started in 1878. About that time, the Federal Government also acquired the more important non-Federal navigation systems on the tributaries and proceeded to improve and extend them. The needs of waterborne commerce prompted Congress in 1910 to authorize 9-foot-depth canalization of the entire Ohio River by a system of locks and movable, navigable dams. The system was completed in 1929. Additional major improvements on principal tributaries were accomplished between the two world wars.

Within the last quarter century, the demand for water transport increased greatly and the traffic pattern changed significantly. To sustain and improve the capacity of the basin system, continuous programs of planning and construction have been underway since 1929 to replace critical obsolete elements. Modernization programs for the tributaries in recent years encompassed the Monongahela, Green, and Cumberland Rivers. The new navigation system on the lower Green River has been completed, and the programs for the other two streams are well advanced.

The current Ohio River modernization plan provides for replacing the existing original 46 navigation structures with 19 dam-lock units. As of July 1965, six of the modern locks and dams were in operation, five under construction, and two in the planning-for-construction stage. The remaining replacement structures were under study.

In July 1965, the study area system of waterways with a maintained minimum depth of 9 feet comprised 1,670 miles, including the 981 miles of the Ohio River. Additional 442 river miles including 93 miles of the Muskingum River maintained by the State of Ohio for recreational boating had a maintained depth of less than 9 feet.

Freight ton-miles moved on the study area waterroutes have increased over the period 1955-65 at an average annual rate of nearly a billion to a total of 27 billion. The greatest share of the basin's waterborne commerce was served by the Ohio River. In 1965 the Ohio River carried 23 billion ton-miles associated with more than 103 million tons of freight. This represented a 16-fold growth in annual ton-miles and a 5-fold growth in tonnage since 1930, the first full year of operation of the Ohio River canalization system. Traffic on the Monongahela River in 1965 was nearly 39 million tons, with lesser movements on other Ohio River tributaries.

By the year 2020, annual tonnage and ton-miles moved on the Ohio River are projected to increase more than five times the 1965 traffic. On the tributaries in the study area, traffic over the same period would grow more than threefold. Additional demand for freight transport by water exists in several areas of the basin which are presently not served by that mode but where potential waterways are expected to be feasible before the year 2010. Should these system extensions be progressively constructed as needed, 6 billion ton-miles are projected to move on 320 new waterway miles by 2020. In that year, the need for transporting cargo on the rivers and canals in the region is expected to reach a total of nearly 150 billion ton-miles, or more than five times the traffic in 1965. This development is portrayed in the following tabulation:

System Segment	Gross Demand for Freight Transport In Billion Ton-Miles Annually			
	1965	1980	2000	2020
Ohio River	23.3	42.0	76.0	127.0
Improved tributaries	4.0	6.1	10.0	14.3
Potential new waterways	-	1.2	4.5	6.1
Total in study area	27.3	49.3	90.5	147.4

Plans for developing the navigation resources in the basin are based on the projected demands for water transport which are in excess of the capabilities of the existing waterways and the facilities of the 1965 program in place. The following tabulation summarizes the projected net demand for waterborne freight traffic that cannot be served by existing developments and those underway:

System Segment	Net Demand In Billion Ton-Miles Annually		
	1980	2000	2020
Ohio River	8.0	42.0	93.0
Improved tributaries	.6	3.6	6.5
Potential new waterways	1.2	4.5	6.1
Total in study area	9.8	50.1	105.6

Traffic on the Ohio River has increased more rapidly than the navigation system can accommodate with efficiency. In the upper third of the stream, four old locks and dams are not included in the 1965 program, and conditions there will become critical by the early 1970's. The replacement of these old navigation structures and the 1965 program will accomplish the modernization plan for the waterway resulting in a system of high-capacity dual locks capable of passing the forecast volumes over the next several decades.

On the tributaries, the following improvements are needed before 1980 in order to maintain the system capabilities, furnish reasonably adequate capacities to meet the expected traffic demand, and provide for an unhampered development of resources and industries in the contiguous areas: (a) elimination of all restrictive facilities on the Monongahela River in accord with the modernization plan for the system, (b) replacement of the old small-capacity Kanawha River locks with larger ones compatible with the Ohio River system, and (c) inclusion of navigation facilities in the Celina Dam project on the Cumberland River and construction of a lock or cargo lift system at Wolf Creek Dam. The capabilities of the Kentucky River for serving modern barge traffic are declining, but no practical solutions are indicated for meeting projected waterborne freight traffic needs in the foreseeable future. The need for new basin waterways is greatest in the areas of the potential Lake Erie-Ohio River Canal and the Wabash River.

Projected tonnage densities will create congestions and delays, which will result, starting about 1980, in a decline in water transport efficiency on the Ohio River. For economical towing operations and to make the capability of the waterway reasonably adequate for the projected traffic, a 12-foot or deeper navigation channel should be constructed in the beginning of the 1980 decade, whether or not this would be concurrent with a completing phase of the lock-and-dam modernization program. Due to the large degree of interdependency between waterborne commerce on the Ohio River and its tributaries, provision of greater depths in the latter should be coincident with or follow closely a deepening of the Ohio River channel. Between 1980 and 2000, additional waterway improvements will be needed on the Allegheny, Green, and Barren Rivers. With a growing demand for low-cost transport of bulk commodities projected for the latter part of the study period, canalization of the Big Sandy River and Levisa Fork will be needed.

Additional measures to augment the waterways' capabilities for meeting the projected needs of waterborne commerce to the year 2020 are expected to be largely managerial and technological in nature. The first named could involve the application of more efficient methods of operation including some form of traffic discipline. Technological improvements are expected to encompass structural facilities and floating and terminal equipment. Advances in towing equipment have and are expected to continue to significantly increase the capabilities of the waterways to carry traffic.

Adequate quantities of lockage water will be available to satisfy all foreseeable future demands arising from waterborne traffic in the existing and potential waterroutes.

The total initial construction cost of the navigation development plan to 2020 - beyond the projects in the 1965 program - is estimated at about $1.8 billion, of which approximately $300 million are for the Ohio River program, $400 million for improvements on tributaries, and $1.1 billion allocated to navigation for new waterway reaches in the study area. The following tabulation shows these costs by system components:

Initial Development Costs, 1966-2020

NOTE. - Cost to complete 1965 programs is excluded

Waterway	Miles	Million Dollars
Ohio River	981	290
Allegheny River	72	80
Monongahela River	131	154
Lake Erie-Ohio River Canal, Ohio Basin section	61	690
Kanawha River	91	110
Big Sandy River-Levisa Fork	127	200
Kentucky River	259	0
Green and Barren Rivers	212	17
Wabash River, section to Terre Haute, Ind.	135	240
Cumberland River	550	25

The total cost is distributed over the study period as follows: About $470 million are costs for projects programmed to 1980, $1.12 billion for additional improvements needed by the year 2000, and $220 million for the remainder of the development plan to 2020. The cost to 1980 includes about $370 million for replacement structures needed to complete the modernization plans for the Ohio and Monongahela River systems and $100 million for facilities on other tributaries. The greater part of the cost of improving existing waterways after 1980 is for deepening the channels in the system: to provide a 12-foot minimum depth, $50 million would be required for the Ohio River, and $73 million, for the tributaries. The cost of needed replacement improvements on the tributaries is $85 million. New waterways needed in the period 1980-2020 would cost $1.13 billion, of which $690 million would be for the Ohio Basin section of the Lake Erie-Ohio River Canal and $240 million for the Wabash River.

Although some of the features of the comprehensive plan are not economically justified at this time, the chance that they will be is considered great enough to warrant their inclusion in the plan. Further detailed studies of every project in the plan will be needed to establish its justification for construction.

To complete the improvements underway and in preconstruction planning in 1965, an additional $785 million need to be expended after July 1, 1965. Of this amount, $753 million would be for Ohio River facilities, $19 million for construction on the Monongahela River, and $13 million allocated to navigation for projects on the Cumberland River.

SECTION II. DEVELOPMENT OF THE WATERWAYS SYSTEM

A. HISTORY OF OHIO RIVER BASIN NAVIGATION

Commercial transportation on the streams of the Ohio River Basin[1] has evolved from the use of bark and dugout canoes and flatbottomed bateaux in the 1600's to the operation of today's diesel-powered bargetows. As the nation grew, the rivers became the highways by which settlers gained access to the inland regions. Communities were established on waterroutes, and the streams became the transportation and communication links between them.

People of the settlement era used mostly flatboats, which were one-way vessels for going downstream. This mode soon proved insufficient for the growing trade between the cities and the frontier, and keelboats answered the need for better water transport. In 1819 it was reported that 500 keelboats were on the Ohio main stem and its tributaries. Although the keelboats lost their lead to the steamboats, they continued in use until after the Civil War on streams too small for river steamers, and even on the Ohio River in periods of low water.

The 1803 Louisiana Purchase opened the mouth of the Mississippi to free navigation, and trade to New Orleans increased so much that flatboats and keelboats alone could not cope with the demand. In 1811, just 4 years after the invention of the steamboat, the river steamer NEW ORLEANS was launched at Pittsburgh and began service between there and New Orleans. Thus was born the era of the packet, which revolutionized river transportation.

As the nation developed, the need for transporting raw materials and manufactured goods brought efforts to link the larger rivers by tributary canalization and man-made, connecting canals. This resulted in the building of a remarkable network of canals by State governments and private enterprise. These waterways helped tie the country together, by connecting the eastern coastal area with the Middle West and speeding the settlement of the Ohio Basin. The explosive expansion of steamboat navigation prompted Congress to authorize the improvement of the streams on a planned systems basis. The first Federal money for river development was appropriated by Congress on May 24, 1824, in "An Act to Improve the Navigation of the Ohio and Mississippi Rivers." The waterways became the lifelines of the country. In 1852 Cincinnati, on the Ohio River, reported steamboat calls at an annual rate of 8,000. At the height of this development, just before the Civil War, the river fleet was carrying more tonnage than that handled by all the vessels of the British Empire.

But the war dealt river transportation a blow from which it would not recover for many years. Hundreds of steamboats were burned, and

[1] Section II and subsection III(A) cover the Tennessee River system, which - though located outside the report's prime study area - is an integral part of the basin's waterways system.

traffic came to a virtual standstill. In the two decades before the Civil War, the railroads were usually short feeders from interior points to the trunkline waterroutes. But in the war years, railroad construction, while very limited in the South, was actively carried on in the States north of the Ohio River, where the network was extended and connected to eastern seaboard lines. Further rapid expansion after peace and severe competition among the railroads (lasting until 1877 when the principal lines entered into a rate agreement) diverted much of the western produce commerce from the Ohio-Mississippi Rivers system to Atlantic ports. Ocean rates to Europe were much lower from the latter than from New Orleans, and only cotton exports, which continued to attract shipping, saved that port from a drastic commercial decline. Interest in the waterways as arteries of freight transport diminished. As to passenger transportation, the once magnificent packets could not meet the demand for fast and reliable service, and this brought about their practical disappearance. This phase, which continued for about 50 years after the war, saw the railroads become leaders in both passenger and freight traffic and waterway transportation shrink to a trickle.

But even then, events were developing that eventually would bring a renaissance to the waterways. The barge had continued to serve commerce by moving some basic bulk commodities such as coal and iron ore. By the latter part of the 19th century, traffic on several streams had revived to such an extent that improving the basin's waterways became of national importance. In 1878 the Federal Government started the 6-foot canalization of the upper Ohio River by a system of movable dams with locks, 110 by 600 feet. In that period, the Government also acquired the State and private navigation systems on the tributaries and proceeded to rebuild and extend these systems to provide an economical means of transport for the resources in the contiguous areas. The investment was justified. By 1890 the combined annual volume of coal traffic on the Ohio, Monongahela, and Kanawha Rivers had reached 10 million tons.[2] In 1905 Congress authorized the provision of a 9-foot depth in the canalization project for the upper 30 miles of the Ohio River.

The outlook for inland navigation became brighter; financial, commercial, and civic organizations with interest in water transport had taken on new life and developed contagious enthusiasm. Realizing that the open-channel improvement of the Ohio River could not provide for a proper development of navigation, Congress in 1910, approved the extension of the 9-foot slack water system throughout the waterway.

However, the prime incentive for efficient water transport came during World War I. The terrific demand upon the transportation system during 1916-18 led the Federal Government in the last year to ease the load by operating barges on the waterways. Later, Congress, through the Transportation Act of 1920, declared its intent to promote, encourage, and develop water transportation. Work was accelerated on the canalization of the

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[2] Short tons of 2,000 pounds are used throughout the report.

Ohio River, which was completed in 1929. The 22 million tons of commerce moving on the Ohio River that year was 50 percent greater than the annual tonnage considered in the plan's justification.

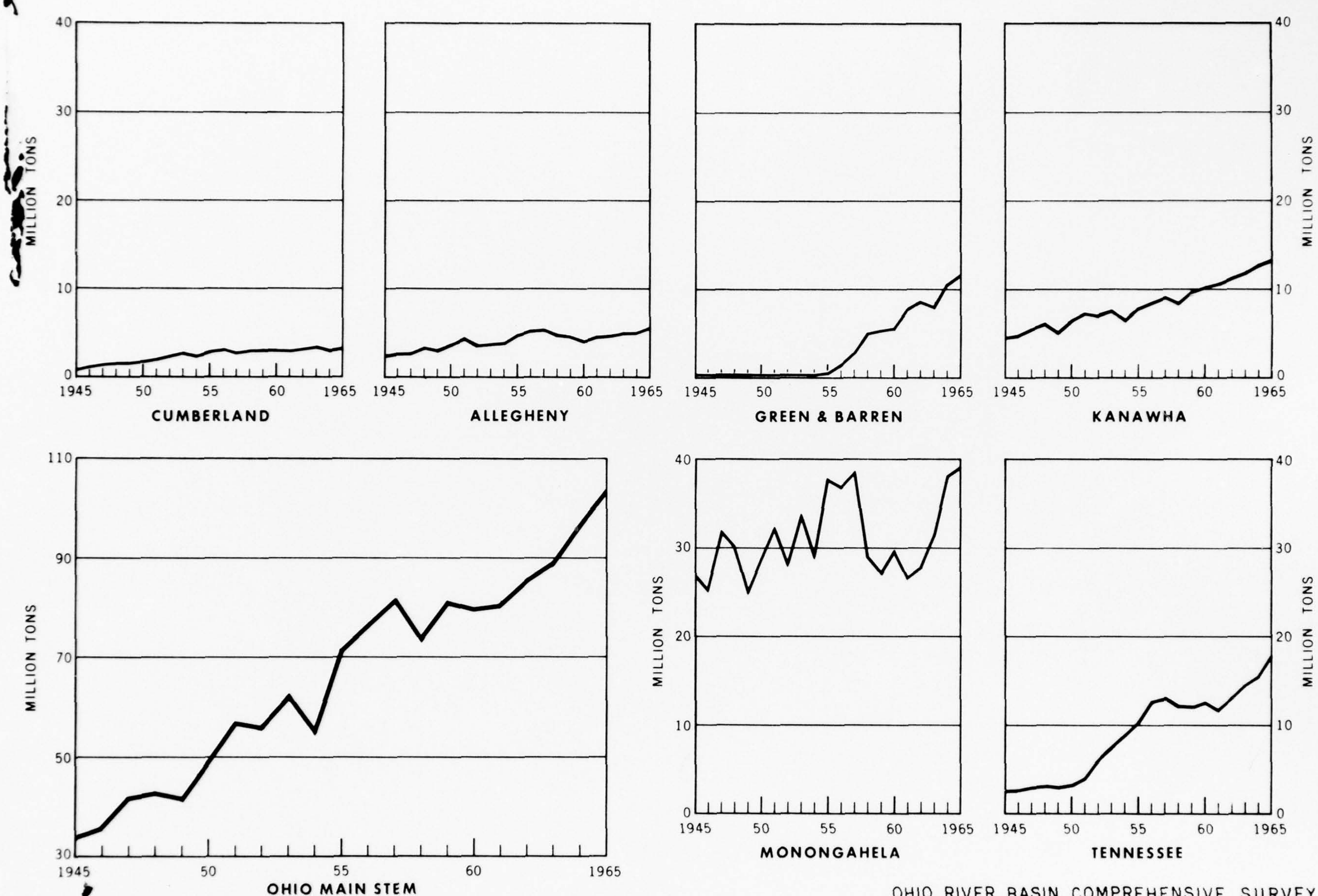
In the three decades following World War I, further improvements were made on the Ohio River, and major improvements were made on the principal tributaries. Development of commerce on the Ohio River system during that period is shown in the following tabulation:

Stream	Total freight traffic in thousand tons			
	1918	1928	1938	1948
Ohio River	6,170	20,940	20,590	42,790
Monongahela River	16,540	27,410	15,330	30,010
Kanawha River	1,280	1,600	3,330	5,910
Allegheny River	2,290	3,480	2,350	3,170
Tennessee River	900	2,270	1,180	3,110
Cumberland River	300	600	500	1,350
Kentucky River	124	145	207	73
Green and Barren Rivers	174	590	230	47

Within the last quarter century, particularly since World War II, both the commerce mix and the traffic pattern on the Ohio River system changed. Whereas Ohio River traffic was once mainly in coal and steel products which moved downstream, new commodities were added to both upriver and downriver commerce. Included were petroleum and its products, dry and liquid chemicals, bauxite, cement, grains, and a variety of other goods. In the early 1950's upstream traffic on the Ohio was approaching the volume of downriver commerce. Tonnages increased greatly in the basin system, as shown graphically in figure 1.

To meet the growing demand for water transportation facilities, Congress has authorized the replacement of obsolete critical elements in the basin's navigation system. Current work includes a modernization program for the Ohio River, which was started in 1954, and completion of modernizing the systems on the Monongahela and the Cumberland Rivers. Several other waterways in the basin, however, became inadequate for the changing commerce and modern tows and, as freight traffic on them declined to insignificance, navigation facilities were deactivated and their maintainance for freight transport ceased. This category of waterroutes includes the Muskingum and Little Kanawha Rivers, the Big Sandy River with its forks, as well as the Rough River and the upper Green River. The Muskingum River lock and dam system was transferred in 1958 to the State of Ohio, which undertook to rehabilitate the waterway for recreational boating.

A more detailed history of navigation in the basin was prepared as background material for this appendix. It is printed in a separate document and is available upon request from the Ohio River Division, Corps of Engineers.



NOTE. — Kentucky River annual tonnage is less than one half million. See subsection III (A).

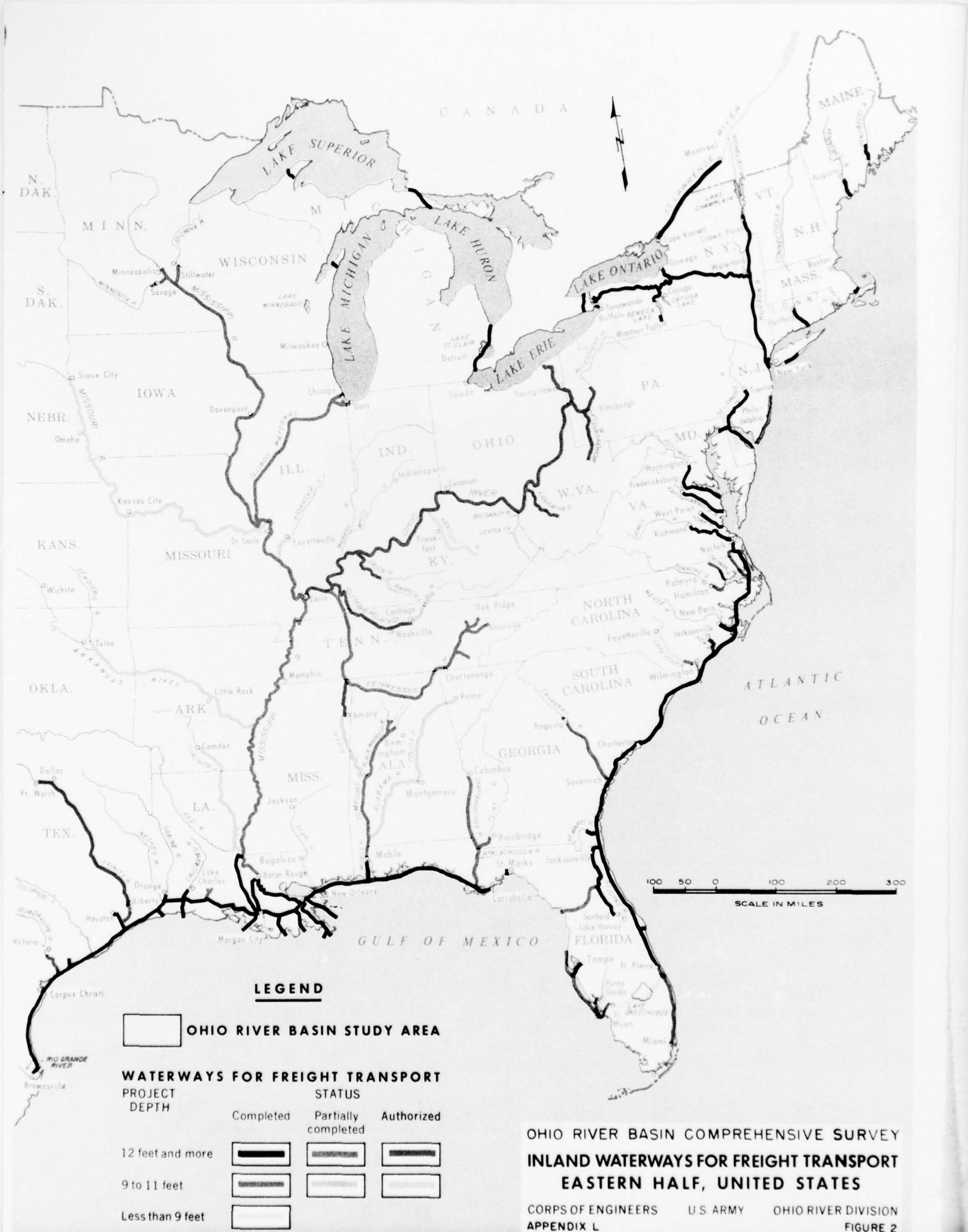
OHIO RIVER BASIN COMPREHENSIVE SURVEY

PRINCIPAL WATERWAYS - OHIO RIVER SYSTEM ANNUAL TONNAGE, 1945-65

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 1

FIGURE 1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

INLAND WATERWAYS FOR FREIGHT TRANSPORT
EASTERN HALF, UNITED STATES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 2

B. PRESENT DEVELOPMENT OF WATERWAYS

The Ohio River system is an integral part of the Mississippi River inland waterways system, which connects to the Great Lakes and the Gulf Intracoastal Waterway. In July 1965, the Ohio River Basin system of waterways with a maintained minimum depth of 9 feet comprised 2,390 miles, of which 1,670 miles were in the study area and 720 miles in the Tennessee Basin. This network accounted for one-half of the total mileage of similar depths in the Mississippi system. In addition, there were 350 miles[1] of waterways in the study area which had a maintained depth of less than 9 feet. Figure 2 shows the relationships of the inland waterways network in the eastern half of the Nation. Figure 3 depicts the July 1965 program for freight-moving navigation in the Ohio River Basin; i.e., those projects which on July 1, 1965, were existing, under construction, and in preconstruction planning.

In 1965 the Ohio River system carried 29.5 billion ton-miles of commerce, of which 27.3 billion were in the study area and 2.2 billion in the Tennessee Valley.

A short description of the waterways in the Ohio River system including their accomplishments (1964) in freight transportation, follows.

1. Ohio River

The Ohio main stem is navigable at a project depth of 9 feet throughout its entire 981 miles. The project width is generally more than 500 feet except at bars with recurrent shoaling, where a channel 300 feet wide is maintained.

The original navigation project as modified in the 1930's, comprised 46 dam-lock structures and the Louisville and Portland Canal around the "Falls of the Ohio" at Louisville, Ky. Most of the units in this system are still in active operation. However, since 1954 a modernization program has been underway. The program provides for continuing the authorized project depth of 9 feet by the progressive replacement of existing structures by a smaller number of new structures of higher lift. As part of this program, the Louisville and Portland Canal, 2 miles long, was widened to 500 feet in 1961.

As of July 1965, five modern dam-lock projects, New Cumberland, Pike Island, Greenup, Meldahl, and Markland, were complete and in operation, and a sixth one, McAlpine, was operative but with some reconstruction underway. These six reduced the number of lockage points on the river from the original 46 to 33. The modern units consist of nonnavigable, gated dams, each

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[1] Not included is the 93-mile canalized waterway on the Muskingum River, which is maintained and operated by the State of Ohio for recreational boating.

with a main lock, 110 by 1,200 feet, and a second lock, 110 by 600 feet. McAlpine has a third lock chamber, 56 by 360 feet. The average lift for these projects is 28.9 feet. Four additional dam-lock structures completed between 1921 and 1937, Emsworth, Dashields, Montgomery Island, and Gallipolis, have nonnavigable dams and two lock chambers. Their main locks are 110 by 600 feet, and their auxiliary locks, 56 by 360 feet, except the Gallipolis auxiliary, which is 110 by 360 feet. The average lift of this group is 17.1 feet. The remaining 23 navigation structures are of the low-head, navigable-dam type. They have single-chamber, 110- by 600-foot locks with an average lift of 8.5 feet.

The July 1965 program included five additional modern units under construction (at Belleville, Racine, Cannelton, Newburgh, and Uniontown) and two in preconstruction planning (Hannibal and Willow Island). When completed, the 7 structures will replace 19 of the 23 low-head lock-and-dam units.

Figure 4 shows in plan and profile the current program for navigation improvements on the Ohio River.

The Ohio main stem navigation system served 96.4 million tons of freight traffic in 1964. This traffic moved 21.3 billion ton-miles - 84.5 percent of the total waterborne ton-miles in the Ohio Basin study area. Traffic density averaged 21.7 million ton-miles per river mile. The highest tonnage density at any one lock (or lock site) on the main stem, occurred at the Cannelton project - 27.7 million tons (28.7 percent of the total annual river tonnage).

By December 1965, two more modern structures (Smithland and Mound City) were in preconstruction planning. When the modernization plan is completed, there will be 19 structures on the Ohio River between Pittsburgh and the mouth.

2. Allegheny River

The present 9-foot canalization project, completed in 1938, extends 72 miles upstream from the rivermouth. The navigation channel has a project width of at least 200 feet. The system comprises eight dam-lock units. These consist of nonnavigable, fixed-crest dams and single locks, 56 by 360 feet. The structures are designed for adding a second lock chamber if and when required. The average lift for these projects is 14 feet. Figure 5 shows in plan and profile the current physical features of the system.

The canalized river section carried 4.87 million tons in 1964. Ton-miles were 57 million - 0.2 percent of the total waterborne ton-miles in the Ohio Basin study area. The resulting ton-miles per mile of waterway were 0.79 million. The lock passing the greatest freight volume was lock No. 2 - 2.74 million tons (56.3 percent of the total annual river tonnage).

3. Monongahela River

The presently authorized project for the Monongahela River provides for 9-foot canalization of its entire length (128.7 miles) with a minimum channel width of 300 feet in the lower 115.4 miles and 250 feet above. By July 1965 the project depth had been provided to mile 115.4, but the depth in the reach above was limited to 7 feet. The channel width varied from full width of the stream at the mouth to about 125 feet in the upper river sections. The modernization and replacement program, started in the late 1940's, has kept the system moving forward to meet the demand.

In July 1965, there were 12 lockage points on the river. The lower six navigation structures each had two locks which ranged in configuration and size from twin chambers (56 by 360 feet and 84 by 720 feet) to a set of main lock, 110 by 720 feet, and auxiliary lock, 56 by 360 feet. The upper six units in the system had single locks, which ranged in size from 56 by 182 feet to 84 by 600 feet. Seven of the navigation structures had fixed-crest dams, one of which was being reconstructed to provide it with a gated crest. Three additional units had gated-crest dams, and the remaining two had gated dams under construction. Completion of the work was to result in eliminating three old, fixed-crest structures and reducing the number of dam-lock units in the system to nine. These will have an average lift of 16.3 feet.

Figure 5 shows in plan and profile the physical development of the Monongahela navigation system as of July 1, 1965.

The Monongahela carried 37.84 million tons of freight in 1964. Ton-miles were 1,772 million, or 7 percent of the total waterborne ton-miles in the Ohio Basin study area. The resulting ton-miles per river mile were 13.77 million. The lock passing the greatest freight volume was lock No. 3 - 22.85 million tons (60.4 percent of the total annual river tonnage).

By October 1967, the modernization program had achieved the goals of reducing to nine the number of lockage points in the stream and providing the authorized channel dimensions throughout the river.

4. Kanawha River

The existing project on the Kanawha River, in West Virginia, completed in 1937, provides for slack water navigation in the 90.6 miles above the mouth. This is attained by a system of four dam-lock units, one of which is Gallipolis Dam on the Ohio River, 13-1/2 miles below the Kanawha mouth. These units, in conjunction with channel dredging, assure a minimum 9-foot depth in the canalized reach. Project width of the navigation channel is a minimum of 300 feet. The three navigation structures in the Kanawha have nonnavigable, gated dams and twin locks, 56 by 360 feet. The average lift is 25.3 feet.

Figure 6 shows in plan and profile the current physical features of the Kanawha River navigation system.

The waterway carried 12.51 million tons of freight in 1964. Ton-miles were 671 million - 2.7 percent of the total waterborne ton-miles in the Ohio Basin study area. Ton-miles per mile of canalized reach were 7.41 million. The lock passing the greatest freight volume was Winfield - 9.57 million tons (76.5 percent of the total annual river tonnage).

5. Kentucky River

The existing canalization project, completed in 1917, provides 6-foot-deep slack water throughout the entire length (258.6 miles) of the Kentucky River. The navigation channel width varies from 400 feet in the lower reach to 250 feet in the upper river. The system comprises 14 dam-lock units. These consist of nonnavigable, fixed-crest dams and single locks. The lower five locks are 38 by 145 feet, and the upper nine, 52 by about 148 feet. The average lift for the 14 structures is 15.4 feet. From the standpoint of modern barging equipment, the system is now obsolescent.

Figure 7 shows in plan and profile the current physical features of the Kentucky River dam-lock system.

In 1964 the Kentucky River carried a freight traffic of 462,000 tons. This traffic moved 30 million ton-miles - 0.1 percent of the total waterborne ton-miles in the Ohio Basin study area. Ton-miles per mile were 120,000. The lock with the highest tonnage density was lock No. 1, which passed 409,000 tons (88.7 percent of the total annual river tonnage).

6. Green and Barren Rivers

The present navigation project for these streams has been in operation since 1956. A system of four dam-lock structures on the Green and one on the Barren River provides for slack water 150 miles up the Green to the mouth of the Barren, thence 30.1 miles up that river to Bowling Green, Ky. Project depth is 9 feet in the modernized lower, 103-mile reach and 5.5 feet above. Private interests, by dredging, have recently extended the 9-foot-deep channel to mile 105.7. Project channel width varies from 200 feet in the lower reach to 100 feet in the upper portion of the system. The navigation structures consist of nonnavigable, fixed-crest dams and single locks. The lower two locks have a modern, 84- by 600-foot chamber. The next two upstream are 36 by 138 feet in size, and the uppermost one is 56 by 360 feet. Dam No. 4 failed in May 1965, and the pool was lost. Lock No. 4 and lock No. 1, Barren River, located at the ends of the drained pool, have since been closed to navigation, and no freight has moved above dam No. 4. Barren River pool No. 1, however, has continued to be used by recreational craft. The average lift for the system is 14.9 feet. This will change to 14.1 feet, when Uniontown Dam, Ohio River, is completed. The ultimate Uniontown pool will reduce the present lift at lock No. 1 by 4 feet. Figure 6 shows in plan and profile the current physical features of the Green and Barren Rivers dam-lock system.

In 1964, 10.36 million tons of freight were transported on the Green and Barren Rivers system. This traffic moved 928 million ton-miles - 3.7 percent of the total waterborne ton-miles in the Ohio Basin study area.

Ton-miles per waterway mile were 5.15 million. The locks with the highest tonnage density were the lower two - each passed 10.11 million tons (97.6 percent of the total annual river tonnage).

7. Cumberland River

The modern 9-foot-depth navigation project was authorized in 1946. Construction under the project (which was modified in 1954) had resulted by July 1965 in a 9-foot navigation channel, which extended 308 river miles to Carthage, Tenn. Its width varied from 300 feet in the lower river to 100 feet in the upper section. At that time, there were six lockage points in the waterway. Listed in an upstream order, these comprised: (a) A modern, 110- by 800-foot lock at Barkley; (b) three old dam-lock structures (remnants of the original 6-foot project) with single, 52- by 280-foot lock chambers; and (c) two modern facilities with single locks, 110 by 800 feet and 84 by 400 feet, at Cheatham and Old Hickory, respectively. The dams of the three old structures were of the nonnavigable, movable-crest type providing an average lift of 11.7 feet. The modern navigation structures have gated or gated-crest dams, one of which was under construction. Completion of the latter was to eliminate the three obsolete structures in the system.

In addition to the aforedescribed structures, there was being built in July 1965 another modern dam-lock unit with a single chamber, 84 by 400 feet, at Cordell Hull. Completion of that project will add a 73-mile upstream extension, 9 feet deep, to the canalized waterway. The ultimate average lift for the four modern dam-lock structures in the river will be 50.5 feet. Also under construction was Barkley Canal between Kentucky Lake, on the Tennessee River, and Lake Barkley, on the Cumberland. The canal, 1.75 miles long and 400 feet wide at the bottom, with a project depth of 11 feet, was to afford a shorter waterroute (by 17 miles) between Lake Barkley and Paducah, on the Ohio River.

Figure 8 shows in plan and profile the physical development of the Cumberland River navigation system as of July 1, 1965.

The Cumberland carried 2.98 million tons of freight in 1964. Ton-miles were 435 million, or 1.7 percent of the total waterborne ton-miles in the Ohio Basin study area. The resulting ton-miles per mile of waterway were 1.41 million. The locks with the highest tonnage density were the two just below Nashville - each passed 2.75 million tons (92.3 percent of the total annual river tonnage).

Lake Cumberland, located 153 miles above the present head of the 9-foot channel, has depths far greater than 9 feet, with a navigation channel extending 90 miles to the vicinity of the Laurel River's mouth. There is no navigation connection to the stream below the lake, and the channel is not part of the current navigation program. Local traffic uses this river section, which carried 37,400 tons in 1965.

By September 1966, Barkley Dam as well as Barkley Canal were completed, and the three obsolete dam-lock units had been removed.

8. Tennessee River and tributaries[2]

The modern 9-foot-depth navigation project for the Tennessee was authorized in 1930, and by 1952 full project dimensions throughout the river were attained. In addition, the high-dam reservoirs on the main river had created several navigable channels along tributary streams.

Construction to improve the waterways has continued over the years, and by July 1965, the navigation system comprised the following physical features: The length of the canalized Tennessee (along the new sailing line) was 630.1 miles - 22 miles shorter than the original river course. This had been achieved by excavating channel cutoffs during reservoir construction and by new channel marking in the deep water created by the impoundments. Channel width was a minimum of 300 feet except in the upper 3.1 miles where it was 150 feet. Significant 9-foot-draft channels extended up the Hiwassee River (18.8 miles), the Clinch River (61.5 miles), and the Emory River (12.1 miles). There were 10 dam-lock units in the system - 9 on the Tennessee main stem and 1 on the Clinch River. Locking facilities in the main river consisted of 110- by 600-foot locks in the lower five dams, a-60- by 265-foot single lock at Hales Bar, and 60- by 360-foot single locks in the upper three. Three of the lower dams had 60-foot-wide auxiliary chambers, which varied in length from 292 to 400 feet. The dams were of the gated or gated-crest type providing an average lift of 56.8 feet. The Clinch River navigation structure consists of a nonnavigable, gated-crest dam with a single lock, 75 to 400 feet. Maximum lift is 60 feet.

A modern navigation structure with a main lock, 110 by 800 feet, and an auxiliary lock, 110 by 600 feet, was under construction on the Tennessee, a few miles below Hales Bar Dam. The new project, known as Nickajack, will replace that dam, which has been plagued by major leakage.

Figure 9 shows in plan and profile the physical development (July 1965) of the navigation system in the Tennessee Valley.

The Tennessee River carried 15.37 million tons of freight in 1964. Ton-miles were 2,054 million - 7.5 percent of the total waterborne ton-miles in the entire Ohio River Basin. Ton-miles per river mile were 3.15 million. The highest tonnage density at any one navigation structure occurred at the Kentucky lock - 7.57 million tons (49.3 percent of the total annual river tonnage).

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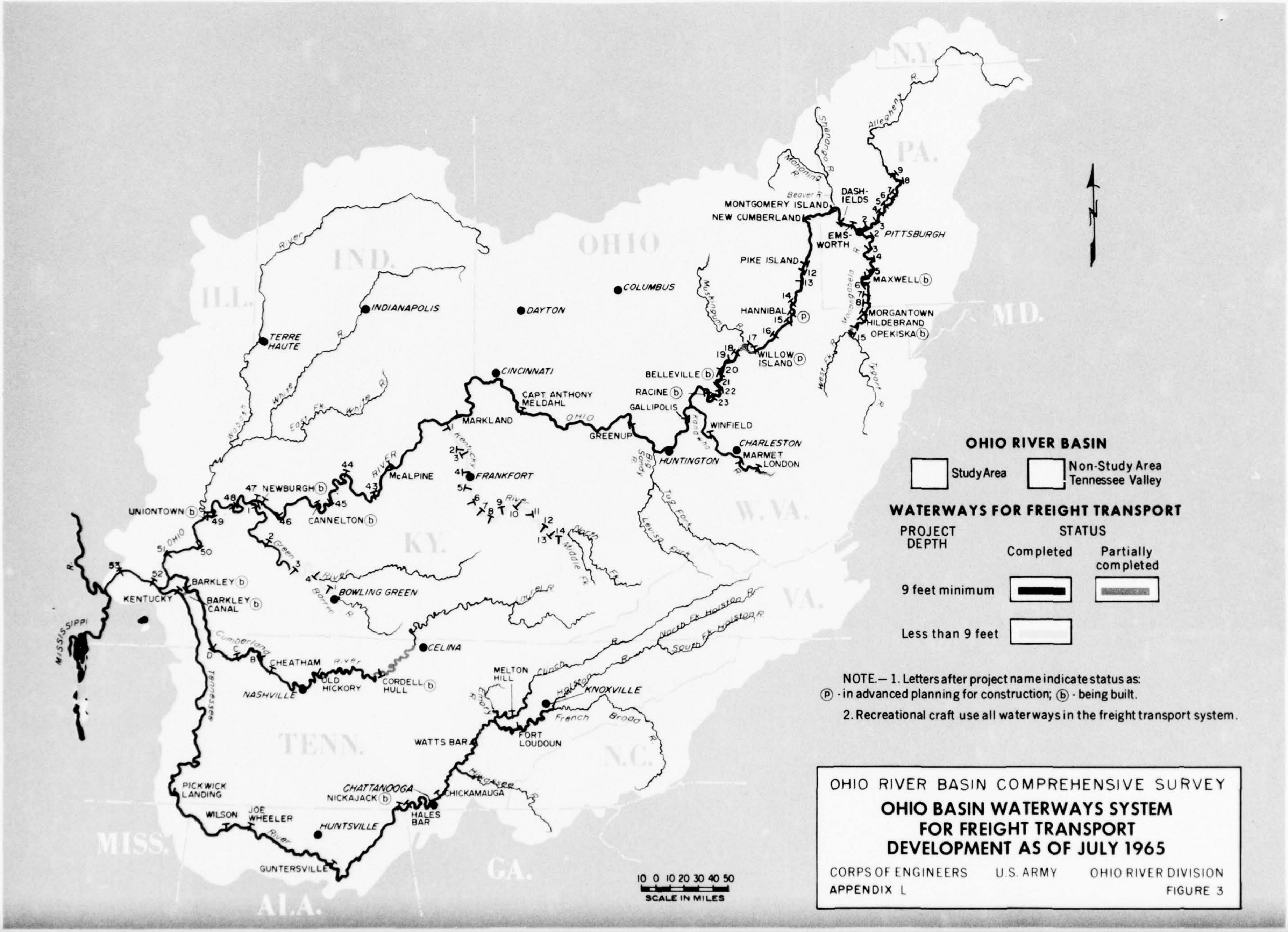
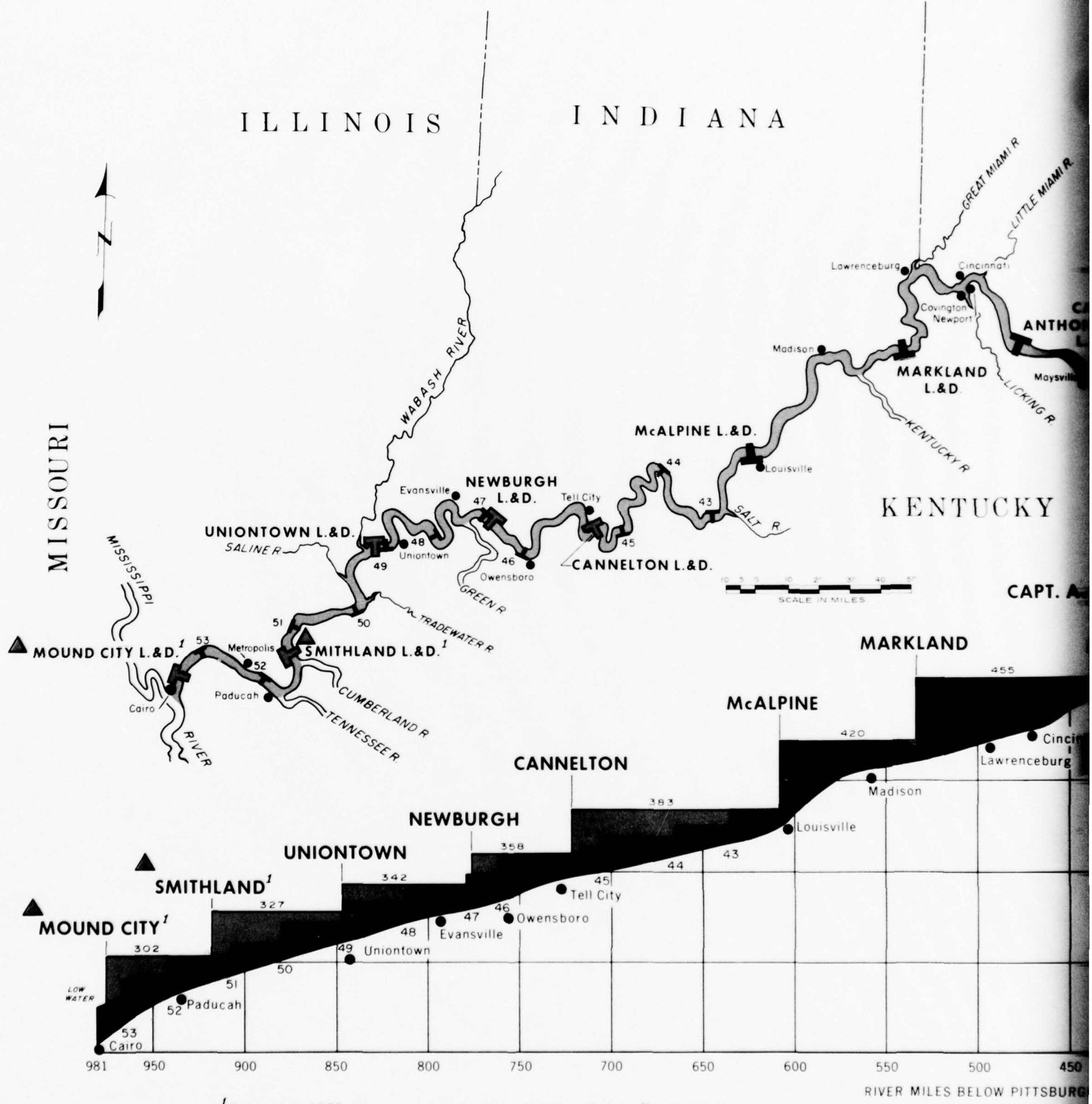
[2] The Tennessee River system - though a part of the Ohio River system - is outside the study area.



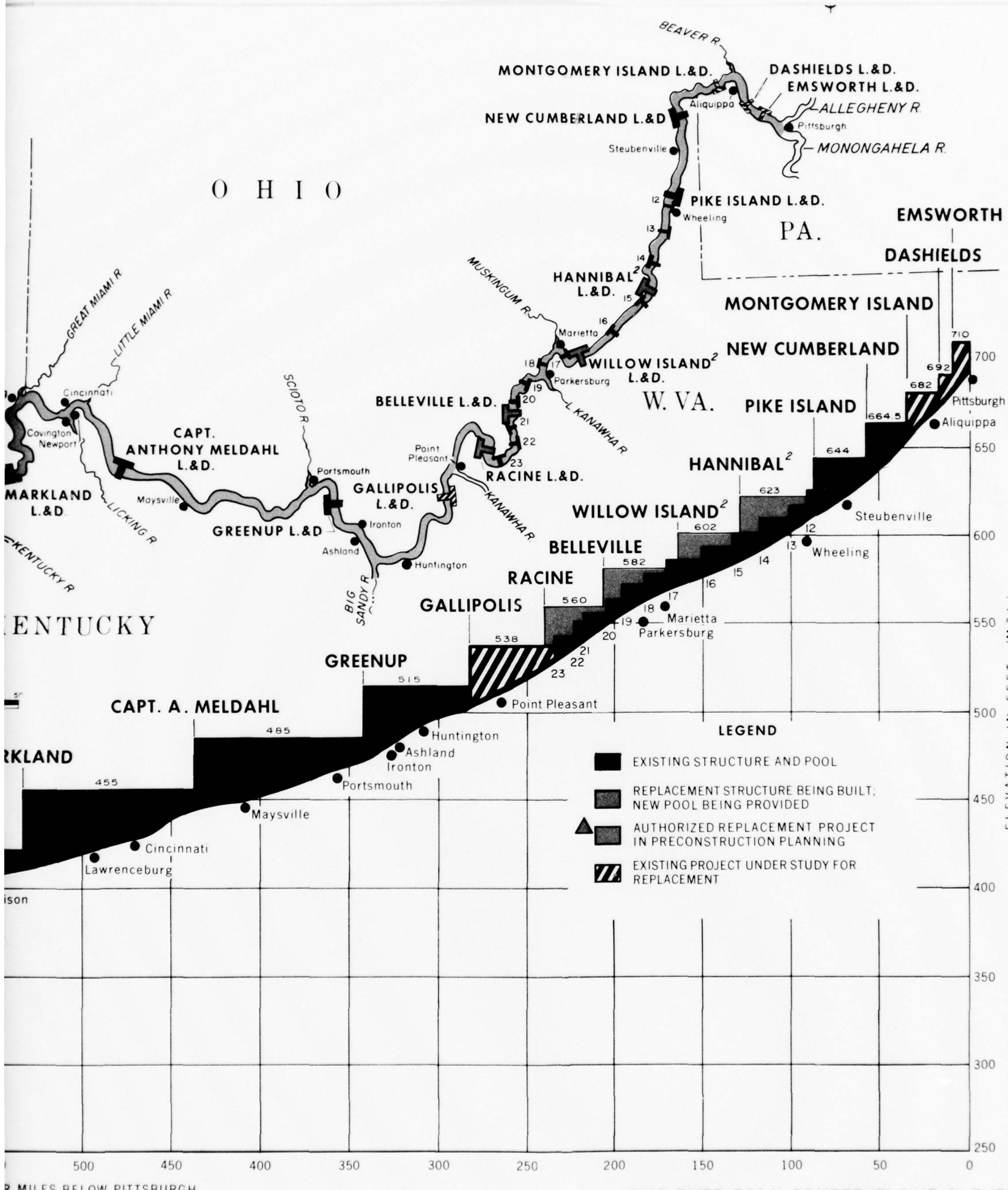
OHIO RIVER BASIN
Study Area
Non-Study Area Tennessee Valley
WATERWAYS FOR FREIGHT TRANSPORT
PROJECT DEPTH
STATUS
Completed
Partially completed
9 feet minimum
Less than 9 feet
NOTE.— 1. Letters after project name indicate status as:
ⓟ - in advanced planning for construction; ⓑ - being built.
2. Recreational craft use all waterways in the freight transport system.
10 0 10 20 30 40 50
SCALE IN MILES
N
N.Y.
PA.
OHIO
IND.
ILL.
MD.
W. VA.
VA.
KY.
TENN.
N.C.
GA.
ALA.
MISS.
PITTSBURGH
DASH-IELDS
EMS-WORTH
MONTGOMERY ISLAND
NEW CUMBERLAND
PIKE ISLAND
HANNIBAL ⓟ
WILLOW ISLAND ⓟ
MAXWELL ⓑ
MORGANTOWN
HILDEBRAND
OPEKISKA ⓑ
BELLEVILLE ⓑ
RACINE ⓑ
GALLIPOLIS
WINFIELD
CHARLESTON
MARMET
LONDON
HUNTINGTON
GREENUP
CAPT ANTHONY MELDAHL
CINCINNATI
COLUMBUS
DAYTON
INDIANAPOLIS
TERRE HAUTE
MARKLAND
FRANKFORT
McALPINE
NEWBURGH ⓑ
CANNELTON ⓑ
UNIONTOWN ⓑ
BOWLING GREEN
BARKLEY ⓑ
BARKLEY CANAL ⓑ
KENTUCKY
CHEATHAM
OLD HICKORY
CORDELL HULL ⓑ
NASHVILLE
CELINA
MELTON HILL
KNOXVILLE
FORT LOUDOUN
WATTS BAR
CHICKAMAUGA
CHATTANOOGA
NICKAJACK ⓑ
HALES BAR
HUNTSVILLE
GUNTERSVILLE
WILSON
JOE WHEELER
PICKWICK LANDING
MISSISSIPPI
OHIO RIVER BASIN COMPREHENSIVE SURVEY
OHIO BASIN WATERWAYS SYSTEM
FOR FREIGHT TRANSPORT
DEVELOPMENT AS OF JULY 1965
CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 3

FIGURE 3



[1] Not in July 1965 program: entered preconstruction status after that date.

[2] Construction started after July 1965.

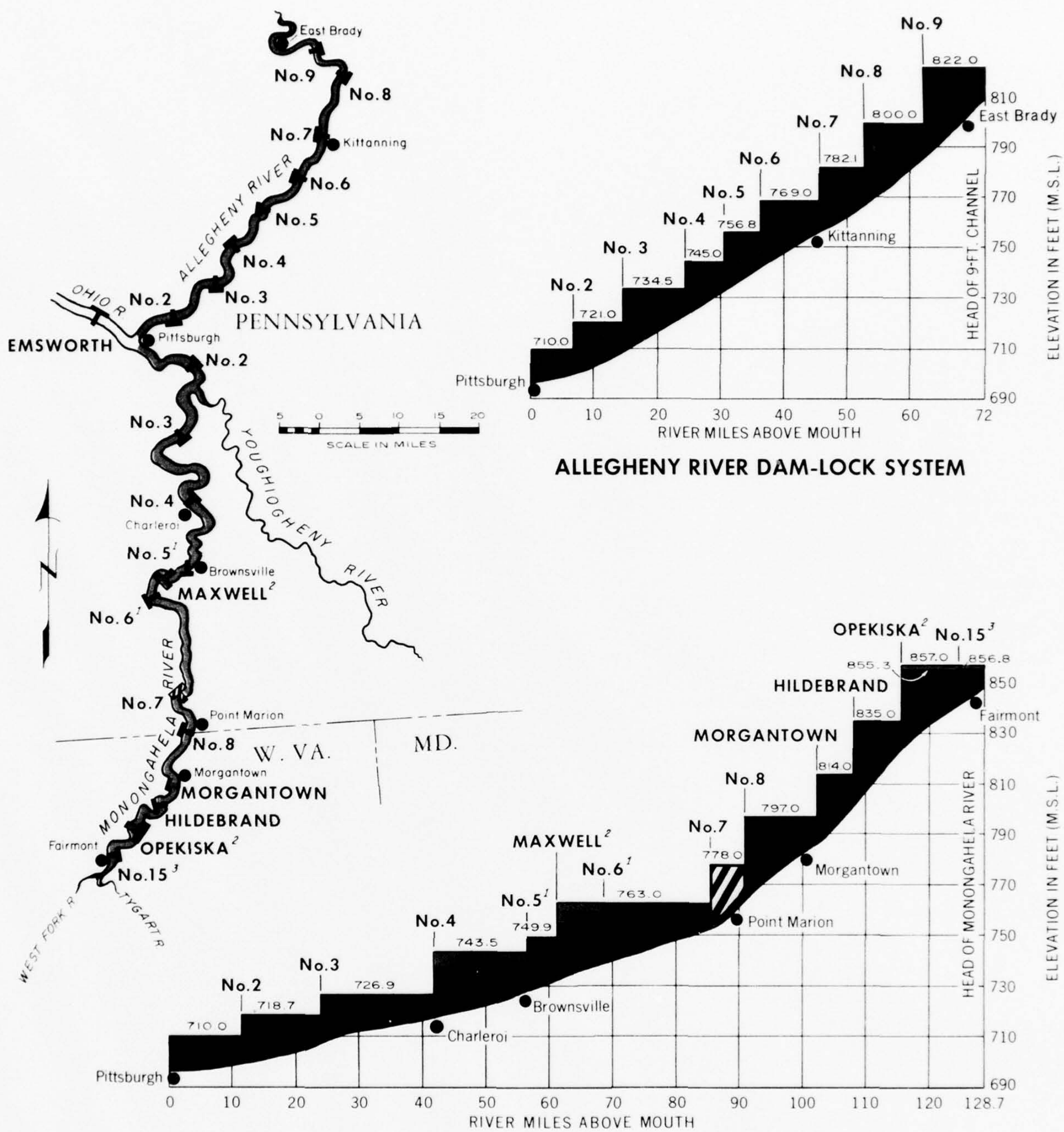


OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO MAIN STEM NAVIGATION SYSTEM GENERAL PLAN AND PROFILE

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 4



[1] Current reconstruction of dam No. 4 and completion of Maxwell Dam will eliminate L & D's Nos. 5 and 6.

[2] Lock completed and in operation; pool raised to elevation shown.

[3] Completion of Opekiska Dam will eliminate L & D No. 15.

LEGEND

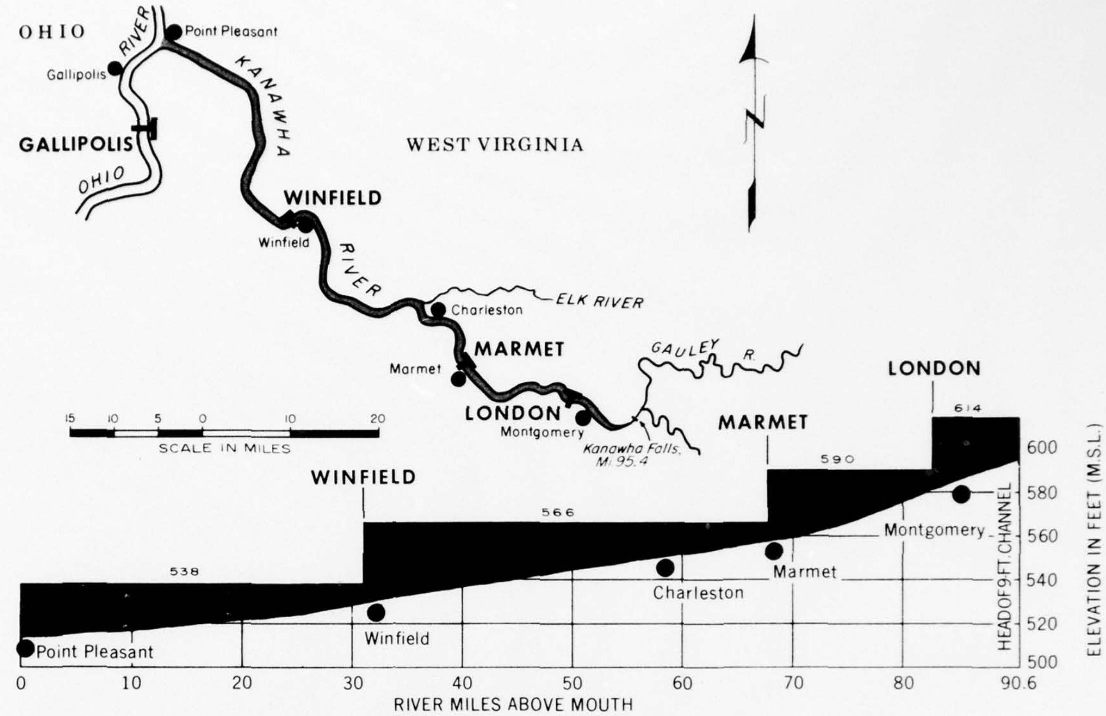
- EXISTING STRUCTURE AND POOL
- REPLACEMENT STRUCTURE BEING BUILT; NEW POOL BEING PROVIDED
- EXISTING PROJECT UNDER STUDY FOR REPLACEMENT

OHIO RIVER BASIN COMPREHENSIVE SURVEY

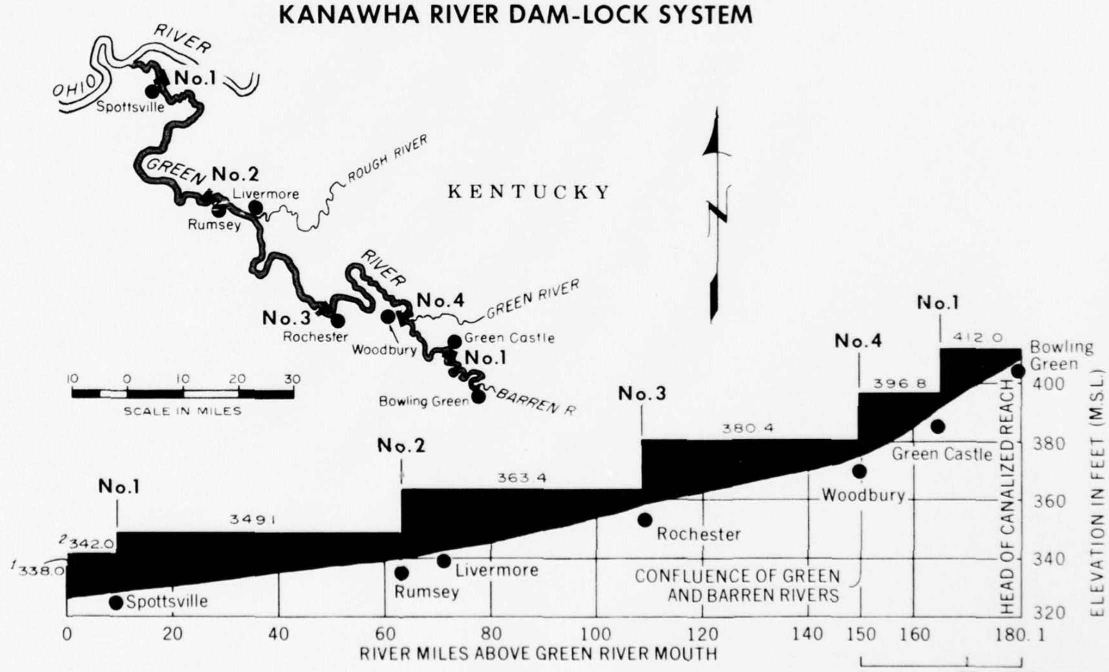
ALLEGHENY AND MONONGAHELA RIVERS NAVIGATION SYSTEMS GENERAL PLAN AND PROFILES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 5



KANAWHA RIVER DAM-LOCK SYSTEM



0 20 30.1
RIVER MILES ABOVE BARREN RIVER MOUTH

GREEN AND BARREN RIVERS DAM-LOCK SYSTEM

[1] Pool above existing Ohio River dam No. 48.

[2] Pool being provided with current construction of Uniontown Dam, Ohio River.

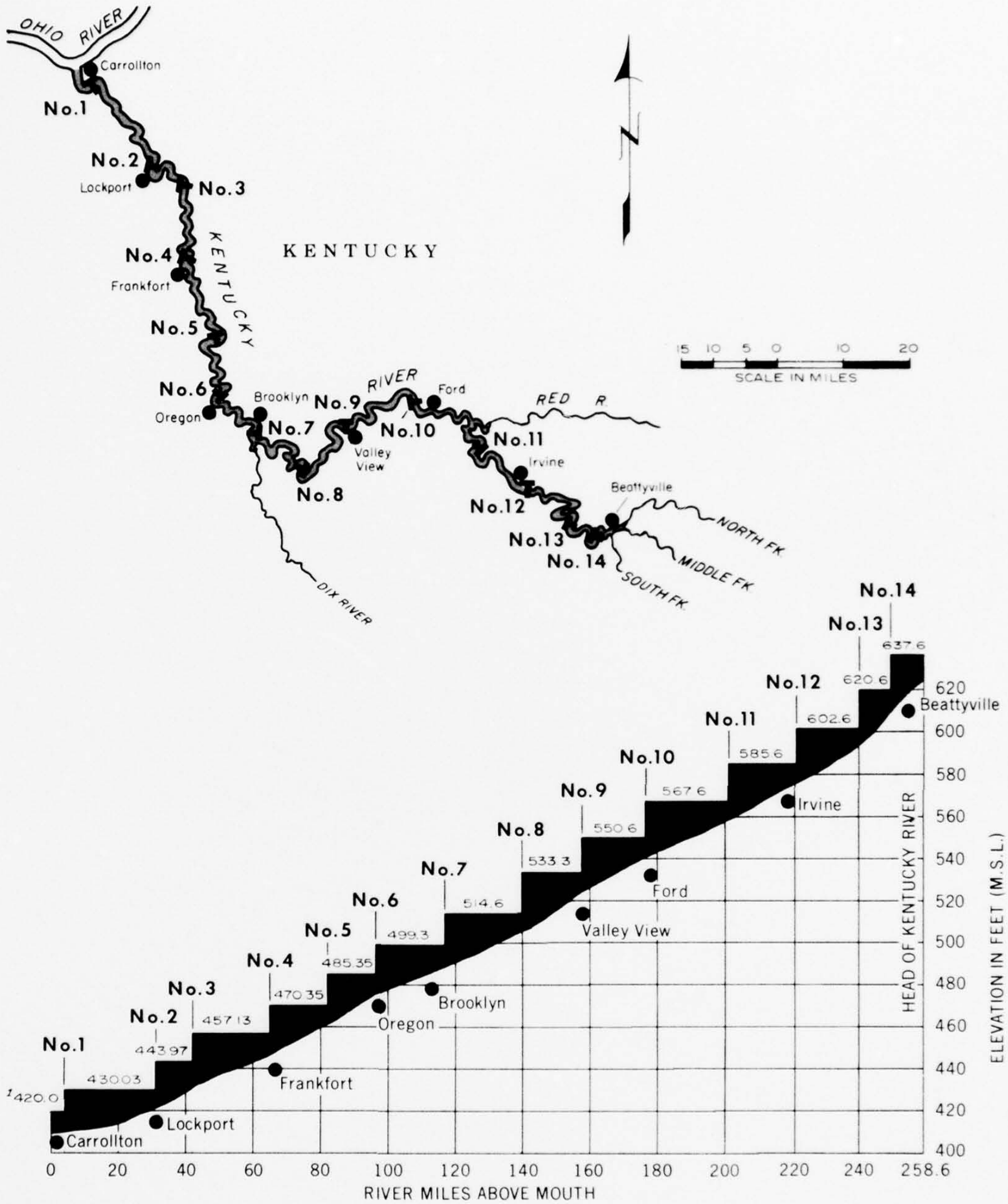
NOTE.— Dam No. 4 failed in May 1965, and the pool was lost. Dam has not been replaced.

LEGEND

- EXISTING STRUCTURE AND POOL
- NEW POOL BEING PROVIDED

OHIO RIVER BASIN COMPREHENSIVE SURVEY
KANAWHA RIVER & GREEN & BARREN RIVERS NAVIGATION SYSTEMS GENERAL PLANS AND PROFILES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 6



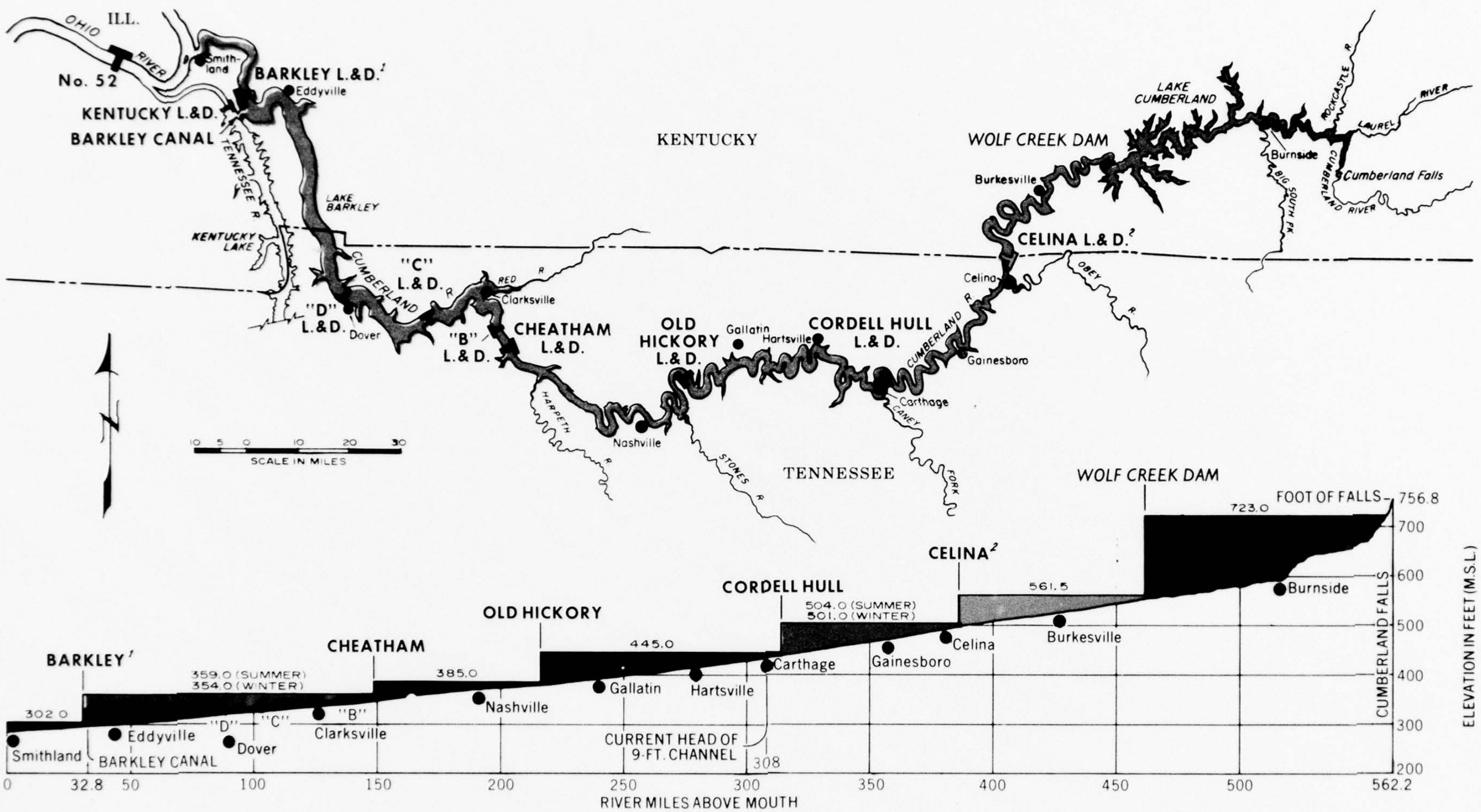
[1] Pool above McAlpine Dam, Ohio River.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

KENTUCKY RIVER NAVIGATION SYSTEM
GENERAL PLAN AND PROFILE

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 7



LEGEND

- EXISTING STRUCTURE AND POOL
- NEW STRUCTURE BEING BUILT; NEW POOL BEING PROVIDED
- AUTHORIZED NEW STRUCTURE AND POOL; NO PRECONSTRUCTION PLANNING STARTED

[1] Lock completed and in operation; pool raised to elevation shown.

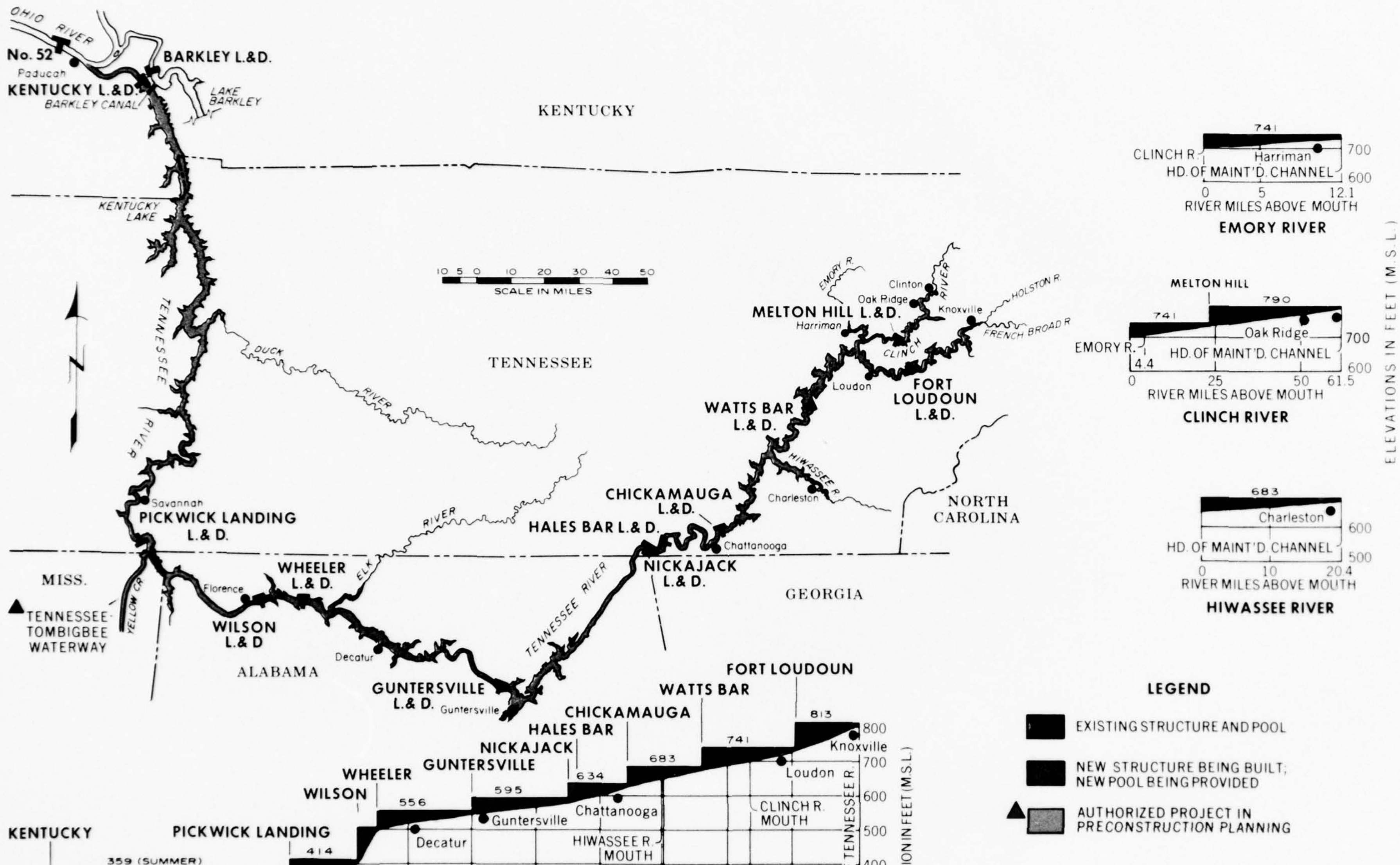
[2] Not in 1965 program.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

CUMBERLAND RIVER NAVIGATION SYSTEM GENERAL PLAN AND PROFILE

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L **FIGURE 8**



OHIO RIVER BASIN COMPREHENSIVE SURVEY

TENNESSEE VALLEY NAVIGATION SYSTEM GENERAL PLAN AND PROFILES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 9

SECTION III. DEMANDS FOR WATER TRANSPORTATION

A. WATERBORNE COMMERCE AND TRENDS

The expansive Mississippi River-Gulf Coast inland waterway system stretching from the Great Lakes to the Mexican border is an inseparable network of trade routes. The Ohio Basin system is a vital part of this vast web of water transport courses spread over the midcontinent of North America. Traffic on these avenues of navigation has grown steadily, and today the network is among the world's greatest in commercial importance. Comparative annual volumes of domestic freight traffic on the three trunklines of the system during the 10-year period, 1955-64, are shown in figure 10.[1]

There is a constant interchange of commerce between the various parts of the great Mississippi River inland waterway system and the connecting navigation systems. A large part of the iron and steel river traffic moves all the way from Pittsburgh to destinations as far apart as the Gulf Coast and Minneapolis, Minn. Crude petroleum and refined products from the Gulf Coast are barged to points ranging over the basin. Coal from the upper Ohio River, western Kentucky, and southern Indiana and Illinois is carried to Chicago, Ill., Florida, and various ports inbetween. A broad variety of chemicals, fertilizers, and sulfur originating at points on the Mississippi and the Gulf Intracoastal Canal move into and through the Ohio River Basin as far as Pittsburgh. Chemicals from Ohio Basin ports and landings are shipped to other parts of the Mississippi River navigation system. Grains from the Upper Mississippi Basin are shipped by way of the Ohio and Tennessee Rivers to markets in the Southeast, while grain traffic originating along the lower Ohio River moves down the Mississippi to foreign lands. Space vehicle parts from Huntsville, Ala., move via the Tennessee and Ohio Rivers to Cape Kennedy, Fla. The tonnage interchange in 1964 among the various system components is shown graphically in figure 11.

Figure 12 illustrates how waterborne commerce in the Ohio Basin is intertwined with that outside the region. The growth of annual tonnages which passed through the mouth of the Ohio River is shown. In 1964, this commerce entering and leaving the Ohio River accounted for 19 percent of the domestic freight tonnage on the Mississippi River and 6.8 percent of that on the Gulf Intracoastal Waterway.

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[1] This appendix reports on domestic freight traffic only, since Ohio Basin foreign traffic (movements to and from foreign countries) is irregular and insignificant. Domestic traffic on the inland waterways (which include intracoastal channels) consists of the following movements:

a. Internal. - Carriage is entirely on inland waterways; or on both the inland and Great Lakes systems; or crosses but short stretches of open waters which link inland systems; and

b. Coastwise. - Carriage is partly over the ocean or the Gulf of Mexico.

There is a direct two-way flow of traffic between the Mississippi River and Great Lakes systems by way of the Illinois Waterway, the Chicago Sanitary and Ship Canal, and the Port of Chicago. Different navigation conditions on these two systems, though, together with the physical limitations of the canal and restriction of tow sizes by municipal ordinance, keep this movement small. The bulk of commerce common to both systems is transshipped in the Chicago area. Figure 13 graphically shows domestic freight tonnages (1964) on the Great Lakes and the tie-in at the Port of Chicago between commerce on the Mississippi River and Great Lakes systems.

Development of freight transport on the principal Ohio Basin navigable reaches for selected years in the period 1950-64 is shown in table 1 for the various classes of commodities. Annual ton-miles of freight carried in the basin in the years 1955-65 are given in figure 14. Figure 15 presents graphically the 1964 tonnages which passed the various locks on the tributaries indicating the relative magnitude and direction of flow of commerce. Similar information for the Ohio main stem is conveyed by figure 16.

The unity of the Ohio River system is illustrated by figure 17. There is a marked degree of interdependency among trade on the various basin and extrabasin waterways. Most of the basin's barged freight is shipped on one waterway and terminated on another. A significant share of the Ohio River's commerce uses the stream as a throughway only. The main stem is the link between its various tributaries and the other parts of the Nation's waterway network. Tables 2 through 9 present the interchange among the various regions in and outside the basin, of waterborne volumes of coal; crude oil and petroleum products; chemicals; and iron and steel.

Recent trends in commerce and traffic patterns on the various waterways in the Ohio River system are presented in the following paragraphs:

1. Ohio River

Six States - Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and Illinois - have direct access to Ohio River waterborne commerce. Principal commodities transported on the stream are coal and coke, petroleum and refined products, sand and gravel, industrial chemicals, iron and steel, and grains.

The development of commerce on the river is shown graphically in figures 18 and 19. The former depicts the growth of commerce for all points along the river between Pittsburgh and Cairo, by comparing the total annual tonnages which passed the points every fifth year from 1930 to 1960 and in 1964 and, in addition, portrays the growth trend of total river tonnage and ton-miles. The latter shows for the various commodity groups, the 1964 tonnage densities along the river. Numerical values for total traffic trends as well as those for the various commodity classes are given in the following tabulation:

Commodity group	Ohio River freight traffic growth: Annual traffic: Tons (millions)	Ton-miles (billions)	Years of growth (number)	Percentage rate of growth: Tonnage	Ton-miles
Coal and coke:					
1930.......	9.77	0.713			
1964.......	46.67	7.351	34	4.7	7.1
Stone, sand, and gravel:					
1930.......	9.53	.160			
1964.......	14.36	.779	34	1.2	4.8
Iron and steel:					
1930.......	1.48	.408			
1964.......	2.87	1.936	34	2.0	4.0
Petroleum and products:					
1930.......	.48	.075			
1964.......	19.14	6.958	34	11.4	14.2
Chemicals and sulfur:					
1952[1]......	1.63	.863			
1964.......	5.73	2.408	12	11.0	8.9
Unclassified:					
1930.......	1.08	.118			
1964.......	7.60	1.892	34	5.9	8.5
Total traffic:					
1930.......	22.34	1.474			
1964.......	96.37	21.325	34	4.4	8.2

[1] First year with separate statistics for both chemicals and sulfur.

The growth rates reflect (a) the increasing needs of the economy for goods and (b) a growing share of water transportation in the total movement of bulk commodities during certain time intervals. Ton-miles growing faster than tonnages indicate increasing average hauls while a reverse growth relationship would be the result of decreasing average hauls, and the variations reflect a changing pattern of origin and destination areas for the particular freight movements.

The total 1964 traffic on the Ohio was about 96 million tons. Only 34 million tons (35 percent) moved exclusively within the confines of the main stem. The remaining 65 percent was either inbound (32 million tons), outbound (18 million tons), or through (12 million tons) traffic. The data show that the dominant part of freight transportation on the Ohio main stem is not confined to the river itself, but is an activity spanning the various waterways in and outside the basin.

2. Allegheny River

The canalized reach of the Allegheny is in Pennsylvania and affords direct access to waterborne commerce on the extensive network of inland

waterways. The lower 6 river miles are part of the Port of Pittsburgh. The following tabulation gives the development of commerce on the canalized river section in the 20 years, 1946-65:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	2.49	1951	4.16	1956	5.15	1961	4.38
1947	2.61	1952	3.44	1957	5.24	1962	4.44
1948	3.17	1953	3.59	1958	4.55	1963	4.75
1949	2.92	1954	3.77	1959	4.03	1964	4.87
1950	3.50	1955	4.63	1960	3.83	1965	5.35

The average annual growth rate for the listed tonnage is 4.1 percent. Associated ton-miles grew at an average rate of 2.1 percent - from 43.14 million to 63.66 million. There is a direct, though flexible, relationship between river freight on the Allegheny and steel output in the Pittsburgh region.

Tonnage densities vary over the canalized reach and are greatest in the lower 16 miles. Figure 15 depicts graphically the 1964 freight volumes (total and by direction) which passed the various locks in the Allegheny and the other Ohio River tributaries.

Figure 17 gives for the various Ohio Basin waterways, the distribution of river traffic, 1964, by origin-and-destination classes. Sixty-three percent of the Allegheny commerce either originated from or was destined for points on other waterways. The principal waterborne commodities in the canalized river section and the respective tonnages are shown in the following tabulation (upriver and downriver volumes include all traffic in the particular direction without regard to points of shipment and receipt):

Commodity	Million tons, 1964		
	Total	Upriver	Downriver
Coal and lignite	2.80	0.41	2.39
Stone, sand, and gravel	1.21	.23	.98
Petroleum products	.39	.36	.03
Iron and steel	.22	.20	.02
Unclassified	.25	.24	.01
Total	4.87	1.44	3.43

3. Monongahela River

The Monongahela River, canalized over its entire length, is in Pennsylvania and West Virginia. The lower 10 river miles are part of the Port of Pittsburgh. The following tabulation gives the development of Monongahela traffic in the 20 years, 1946-65:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	25.43	1951	32.03	1956	36.96	1961	26.76
1947	31.74	1952	28.08	1957	38.42	1962	27.78
1948	30.01	1953	33.37	1958	28.91	1963	31.38
1949	25.25	1954	28.94	1959	27.17	1964	37.84
1950	28.51	1955	37.62	1960	29.53	1965	38.82

The average annual growth rate for the listed tonnage is 2.3 percent. Associated ton-miles grew at an average rate of 1.9 percent - from 1.250 billion to 1.790 billion. As on the Allegheny, there is a direct, though flexible, relationship between river freight on the Monongahela and steel output in the Pittsburgh region.

Tonnage densities vary over the stream and are greatest in the reach between miles 20 and 63. Nearly one-half of the 1964 commerce either originated on or was destined for other waterways or both. Much of the outbound and inbound traffic was from or to the river section lying in the Port of Pittsburgh. The principal waterborne commodities and the respective tonnages are shown in the following tabulation (upriver and downriver volumes include *all traffic in the particular* direction without regard to points of shipment and receipt):

Commodity	Million tons, 1964		
	Total	Upriver	Downriver
Coal and coke	31.56	4.13	27.43
Stone, sand, and gravel	2.24	1.87	.37
Iron and steel	1.76	.97	.79
Petroleum and products	1.31	1.29	.02
Chemicals and sulfur	.61	.11	.50
Unclassified	.36	.28	.08
Total	37.84	8.65	29.19

4. Kanawha River

The canalized reach of the Kanawha lies entirely in West Virginia. The following tabulation gives the development of tonnages on the stream during the 20 years, 1946-65:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	4.52	1951	7.09	1956	8.37	1961	10.51
1947	5.37	1952	6.90	1957	8.88	1962	11.14
1948	5.91	1953	7.42	1958	8.21	1963	11.78
1949	4.96	1954	6.37	1959	9.71	1964	12.51
1950	6.39	1955	7.64	1960	10.08	1965	13.18

The average annual growth rate for the listed tonnage is 5.8 percent. Associated ton-miles grew at an average rate of 5.9 percent - from 0.237 billion to 0.706 billion.

Tonnage densities are greatest and fairly constant in the lower 54 river miles; farther up, they drop off gradually towards the head of navigation. More than three-fourths of the 1964 commerce came from or was destined for other waterways. The principal waterborne commodities and the respective tonnages are shown in the following tabulation (upriver and downriver volumes include all traffic in the particular direction without regard to points of shipment and receipt):

Commodity	Million tons, 1964		
	Total	Upriver	Downriver
Coal and coke	7.60	1.02	6.58
Chemicals and sulfur	3.21	2.77	.44
Petroleum and products	.69	.64	.05
Stone, sand, and gravel	.59	.59	0
Unclassified	.42	.37	.05
Total	12.51	5.39	7.12

5. Kentucky River

The Kentucky River system with its 6-foot depth and small locks is now obsolescent for modern barging operations. This is reflected in the small volumes of waterborne freight, which reached a low point in 1951. In 1952 downbound shipments of coal were started from Beattyville, Ky., to points on the Kentucky River, helping to reverse the traffic trend. River commerce kept growing to 1964 when water transport of coal ceased. The following tabulation shows the annual river tonnage, 1946-65:

Year	Thousand tons	Year	Thousand tons	Year	Thousand tons	Year	Thousand tons
1946	121	1951	66	1956	211	1961	427
1947	84	1952	87	1957	257	1962	432
1948	73	1953	91	1958	317	1963	417
1949	75	1954	132	1959	398	1964	462
1950	74	1955	175	1960	400	1965	319

The average annual growth rate for the total tonnage, between the first full year (1953) and the last year (1964) of Beattyville coal shipments, was 15.9 percent. Associated ton-miles grew at an average rate of 8.8 percent - from 11.72 million to 29.75 million. The drop, 1964-65, in tonnage was 31 percent and that in ton-miles, 29 percent. Tonnage densities are greatest and fairly constant in the lower 68 river miles (to Frankfort, Ky.). Nearly 90 percent of the 1964 cargo on the river originated on the Ohio main stem. The principal waterborne commodities and

the respective tonnages are shown in the following tabulation (downbound volumes moved only within confines of the river):

Commodity	Thousand tons, 1964 Total	Inbound	Downbound
Stone, sand, and gravel	341	341	0
Gasoline	68	68	0
Bituminous coal and lignite	53	0	53
Total	462	409	53

Traffic on the Kentucky River consists now mainly of private recreational craft; the greatest use of the locks in the system is by these vessels.

6. Green and Barren Rivers

The Green and Barren Rivers navigation project gives the west-central part of the Commonwealth of Kentucky a direct connection to commerce in the Mississippi River and connecting waterway systems. Traffic on the original project, with its 5.5-foot depth and small locks, reached a low point (about 25,000 tons) in 1947. The canalized rivers had become obsolete for modern barging operations. But the increased needs of the greatly expanded steamelectric power facilities in the Ohio Basin, for coal from Green River mines, led to the modernization of the lower 103 miles of the project. Two new locks as well as a 9-foot-deep channel were provided in 1956, and river movements of coal from the reach, miles 80 to 105, increased sharply.

The following tabulation gives the tonnage by years between 1946 and 1965:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	0.03	1951	0.07	1956	1.25	1961	7.59
1947	.02	1952	.09	1957	2.69	1962	8.49
1948	.05	1953	.06	1958	4.79	1963	7.76
1949	.05	1954	.21	1959	5.17	1964	10.36
1950	.04	1955	.41	1960	5.45	1965	11.31

The average annual tonnage growth rate between 1957, the first full year of operation for the modernized lower reach, and 1965 was 19.6 percent. Associated ton-miles grew at an average rate of 20.4 percent - from 233 million to 1.03 billion.

In the lower 85 river miles, tonnage densities are greatest and fairly constant. They drop off somewhat between miles 85 and 105, but farther up, only small volumes were moved until dam No. 4's failure and none since then. Of the total 10.36 million tons carried in 1964, 10.11 million were

coal and lignite shipments to other waterways. The remainder was mostly coal and lignite (250,000 tons) downbound to points on the river and small amounts of inbound gasoline.

7. Cumberland River

The modern waterway to Carthage, Tenn. provides the contiguous areas in Kentucky and Tennessee with access to the vast network of waterroutes from the Great Lakes to the Mexican border. The following tabulation gives the development of Cumberland River tonnages during the 20 years, 1946-65:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	1.03	1951	1.78	1956	3.04	1961	2.84
1947	1.21	1952	2.17	1957	2.67	1962	3.13
1948	1.35	1953	2.49	1958	2.86	1963	3.37
1949	1.48	1954	2.23	1959	2.90	1964	2.98
1950	1.65	1955	2.88	1960	2.81	1965	3.03

The average annual growth rate for total tonnage between 1946 and 1963 was 8.5 percent and that for the associated ton-miles, 9.3 percent. The sudden 11.8 percent decrease, 1964, in waterborne tons and ton-miles was due to the extension to Nashville of a pipeline, which began serving a good part of the regional gasoline needs. Preliminary statistics however indicate that river commerce has recovered from this setback. Total 1966 tonnage and ton-miles have exceeded the previous high marks of 1963, with petroleum products still at the 1964 level.

Tonnage densities are fairly constant in the lower 190 river miles, with peaks in the reach between Clarksville and Nashville. Upstream of the latter city, tonnage is small. More than two-thirds of the 1964 riverborne freight came from or was destined for other waterways. The volumes of the principal waterborne commodities are shown in the following tabulation:

Commodity	Million tons, 1964 Total	Upriver	Downriver
Petroleum products	1.41	1.41	0
Stone, sand, and gravel	1.31	1.23	.08
Iron and steel	.10	.08	.02
Chemicals and sulfur	.11	.10	.01
Unclassified	.05	.02	.03
Total	2.98	2.84	0.14

Only 90,000 tons of the volumes presented in the tabulation moved on the river section above Nashville, 80,000 inbound, and 10,000 outbound. All these were chemicals.

8. Tennessee River

The Tennessee Valley navigation system serves a vital part of Tennessee and parts of Georgia, Alabama, Mississippi, and Kentucky. The Tennessee River carries traffic which directly affects waterborne commerce in the prime study area. Annual river tonnage for the period 1946-65 is listed in the following tabulation:

Year	Million tons	Year	Million tons	Year	Million tons	Year	Million tons
1946	2.40	1951	3.75	1956	12.30	1961	11.61
1947	2.79	1952	5.84	1957	12.74	1962	13.12
1948	2.96	1953	7.12	1958	12.04	1963	14.43
1949	2.77	1954	8.42	1959	12.04	1964	15.37
1950	3.05	1955	9.98	1960	12.44	1965	17.40

The average annual tonnage growth rate between 1946 and 1965 was 11 percent. Principal commodities transported on the Tennessee are coal, grain, petroleum products, sand, gravel, and crushed rock. More than one-half of the 1964 river tonnage was either shipped or received on another waterway, or both.

About half of the tonnage carried on the Tennessee also moves on the waterways in the prime study area. The following tabulation shows annual tonnages which were inbound to or outbound from the Tennessee past its mouth on the Ohio. The data illustrates the impact of Tennessee River freight movements on Ohio main stem traffic.

	Million tons through the Tennessee River mouth					
	1960			1964		
	In-bound	Out-bound	Total	In-bound	Out-bound	Total
Coal and coke............	1.375	0.108	1.483	1.996	0.187	2.183
Petroleum products.......	.792	0	.792	.866	.005	.871
Grains...................	2.170	.005	2.175	1.695	.004	1.699
Chemicals and sulfur.....	.180	.172	.352	.136	.207	.343
Unclassified.............	.484	.852	1.336	.864	1.694	2.558
Total...............	5.001	1.138	6.139	5.557	2.098	7.655
Percent of total Tennessee traffic			49.3			49.8
Percent of total Ohio River traffic			7.7			7.9

TABLE 1. - FREIGHT TRANSPORT ON THE OHIO RIVER NAVIGATION SYSTEM, 1950-64, BY COMMODITIES, IN MILLION TONS

Stream and year	Commodity group: Coal and coke	Petroleum and products	Iron and steel	Chemicals and sulfur	Stone, sand, and gravel	Unclassified	Total freight traffic[1]
Ohio River							
1950	23.86	11.73	2.28	1.29	8.25	1.18	48.60
1955	37.96	14.52	4.22	2.08	9.96	2.72	71.46
1960	39.90	16.34	3.68	3.78	10.14	5.64	79.48
1964	46.67	19.14	2.87	5.73	14.36	7.60	96.37
Kanawha River							
1950	4.75	0.50	0.005	0.67	0.37	0.10	6.39
1955	5.81	.51	.06	.84	.28	.15	7.64
1960	6.65	.53	.04	2.04	.59	.23	10.08
1964	7.60	.69	.02	3.21	.59	.40	12.51
Allegheny River							
1950	1.82	0.22	0.08	0.002	1.33	0.05	3.50
1955	2.62	.25	.19	.02	1.33	.22	4.63
1960	2.06	.24	.26	.03	1.11	.13	3.83
1964	2.80	.39	.22	.04	1.21	.21	4.87
Kentucky River							
1950	0.010	0.045	-	-	0.019	-	0.074
1955	.054	.067	0.001	-	.053	-	.175
1960	.160	.065	.001	-	.173	-	.400
1964	.052	.068	-	-	.341	-	.462

Stream and year	Commodity group: Coal and coke	Petroleum and products	Iron and steel	Chemicals and sulfur	Stone, sand, and gravel	Unclassified	Total freight traffic[1]
Monongahela River							
1950	23.05	0.77	1.56	0.48	2.50	0.15	28.51
1955	30.20	1.15	2.43	.62	2.42	.80	37.62
1960	23.74	1.25	1.85	.44	1.57	.68	29.53
1964	31.56	1.31	1.76	.61	2.24	.36	37.84
Green and Barren Rivers							
1950	-	0.04	-	-	-	-	0.04
1955	0.20	.06	0.001	-	0.13	0.02	.41
1960	5.44	.01	-	-	-	.001	5.45
1964	10.35	.01	-	-	-	.002	10.36
Cumberland River							
1950	-	0.86	0.05	0.02	0.67	0.05	1.65
1955	0.01	1.15	.10	.04	1.21	.37	2.88
1960	-	1.55	.09	.06	1.03	.08	2.81
1964	-	1.41	.10	.11	1.31	.05	2.98
Tennessee River							
1950	0.21	0.75	0.11	0.03	1.66	0.30	3.05
1955	5.66	.92	.16	.14	1.87	1.23	9.98
1960	5.18	.79	.23	.36	2.34	3.54	12.44
1964	6.33	.88	.20	.37	3.27	4.33	15.37

[1] Commodity group amounts may not add to total due to rounding.

TABLE 2. - COAL, AREA-TO-AREA WATER SHIPMENTS IN 1960, IN THOUSAND TONS

Origin area	Destination area: Ohio River main stem reaches[1]			Tributaries							Extra-basin	Total shipped
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Green-Barren	Ken-tucky	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny		
Ohio River main stem reaches:												
Miles 981-438	4,093	-	-	1,261	-	-	-	-	-	-	1,000	6,354
Miles 438-109	3,532	3,511	2,172	50	-	-	95	-	1,319	-	456	11,135
Miles 109-0	-	155	1,870	-	-	-	-	-	38	2	3	2,068
Tributaries:												
Tennessee	-	-	-	3,695	-	-	-	-	-	-	108	3,803
Tradewater	-	-	-	27	-	-	-	-	-	-	-	27
Green-Barren	4,311	-	-	-	198	-	-	-	-	-	928	5,437
Kentucky	-	-	-	-	-	160	-	-	-	-	-	160
Kanawha	2,447	1,846	21	-	-	-	1,973	147	65	-	25	6,524
Monongahela	-	1,260	7,394	-	-	-	-	-	13,385	108	1	22,148
Allegheny	-	-	1,561	-	-	-	-	-	-	391	-	1,952
Extrabasin	-	-	-	-	-	-	-	-	-	-		-
Total received	14,383	6,772	13,018	5,033	198	160	2,068	147	14,807	501	2,521	59,608

[1] Division into reaches follows current practice of presenting waterborne commerce statistics for the stream. Mile 0 is at The Point in Pittsburgh, Pa. (confluence of Allegheny and Monongahela Rivers).

TABLE 3. - COAL, AREA-TO-AREA WATER SHIPMENTS IN 1964, IN THOUSAND TONS

Origin area	Destination area											
	Ohio River main stem reaches			Tributaries								
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Green-Barren	Ken-tucky	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:												
Miles 981-438	4,045	1	-	1,346	-	-	-	-	7	-	1,596	6,995
Miles 438-109	887	3,785	2,408	297	-	-	-	-	3,341	-	610	11,328
Miles 109-0	-	363	2,243	-	-	-	-	-	97	-	-	2,703
Tributaries:												
Tennessee	-	-	-	4,145	-	-	-	-	-	-	187	4,332
Green-Barren	8,082	-	-	322	250	-	-	-	-	-	1,700	10,354
Kentucky	-	-	-	-	-	52	-	-	-	-	-	52
Kanawha	1,853	2,775	194	-	-	-	2,718	3	4	-	35	7,582
Monongahela	1	1,469	7,224	-	-	-	-	-	18,869	411	-	27,974
Allegheny	-	-	1,472	-	-	-	-	-	-	911	-	2,383
Extrabasin	-	-	-	-	-	-	-	-	-	-		-
Total received	14,868	8,393	13,541	6,110	250	52	2,718	3	22,318	1,322	4,128	73,703

TABLE 4. - PETROLEUM AND REFINED PRODUCTS, AREA-TO-AREA WATER SHIPMENTS IN 1960, IN THOUSAND TONS

Origin area	Destination area												
	Ohio River main stem reaches			Tributaries									
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Cumber-land	Green-Barren	Ken-tucky	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:													
Miles 981-438	1,329	2,412	259	379	153	9	61	100	-	95	76	695	5,568
Miles 438-109 [1]	1,043	291	924	68	56	-	-	61	-	398	21	40	2,902
Miles 109-0	70	48	47	-	-	-	-	1	2	95	19	21	303
Tributaries:													
Tennessee	-	-	-	2	-	-	-	-	-	-	-	-	2
Cumberland	-	-	-	-	-	-	-	-	-	-	-	4	4
Kanawha	-	28	2	-	-	-	-	-	-	14	-	26	70
Monongahela	1	7	112	-	-	-	-	-	-	42	-	1	163
Allegheny	-	1	4	-	-	-	-	1	-	17	-	35	58
Extrabasin	2,897	1,051	762	430	1,254	-	-	291	23	450	61		7,219
Total received	5,340	3,838	2,110	879	1,463	9	61	454	25	1,111	177	822	16,295

[1] Includes shipments of 64,000 tons originating on the Big Sandy River.

TABLE 5. - PETROLEUM AND REFINED PRODUCTS, AREA-TO-AREA WATER SHIPMENTS IN 1964, IN THOUSAND TONS

	Destination area											
	Ohio River main stem reaches			Tributaries								
Origin area	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Cumber-land	Green-Barren	Ken-tucky	Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:												
Miles 981-438	1,818	3,744	498	275	166	8	68	117	52	90	838	7,674
Miles 438-109 [1]	1,006	391	1,031	76	028	-	-	104	408	19	37	3,100
Miles 109-0	64	87	92	-	-	-	-	-	114	-	4	361
Tributaries:												
Tennessee	1	-	-	6	-	-	-	-	-	-	4	11
Cumberland	-	-	-	-	2	-	-	-	-	-	-	2
Kanawha	21	9	6	-	-	-	-	1	4	-	6	47
Monongahela	4	3	5	-	-	-	-	-	35	-	1	48
Allegheny	-	1	1	-	-	-	-	1	22	-	3	28
Extrabasin	3,286	[2] 684	810	904	1,169	-	-	417	659	252		8,181
Total received	6,200	4,919	2,443	1,261	1,365	8	68	640	1,294	361	893	19,452

[1] Includes shipments of 737,000 tons originating on the Big Sandy River.

[2] Includes shipments to -
Big Sandy River of 7,000 tons and
Little Kanawha River of 60,000 tons.

TABLE 6. - CHEMICALS, AREA-TO-AREA WATER SHIPMENTS IN 1960, IN THOUSAND TONS

Origin area	Destination area										
	Ohio River main stem reaches			Tributaries							
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Cumber-land	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:											
Miles 981-438	14	24	5	21	-	39	-	-	-	24	127
Miles 438-109	73	57	3	8	-	783	12	-	-	110	1,046
Miles 109-0	22	10	228	8	2	27	1	9	3	57	367
Tributaries:											
Tennessee	67	-	6	9	-	24	11	-	-	50	167
Kanawha	19	20	7	1	-	168	13	-	-	142	370
Monongahela	-	56	76	1	-	22	-	131	-	49	335
Allegheny	-	-	-	-	-	-	-	-	-	1	1
Extrabasin	144	12	129	29	22	658	-	33	23		1,050
Total received	339	179	454	77	24	1,721	37	173	26	433	3,463

TABLE 7. - CHEMICALS, AREA-TO-AREA WATER SHIPMENTS IN 1964, IN THOUSAND TONS

Origin area	Destination area										
	Ohio River main stem reaches			Tributaries							
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Cumber-land	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:											
Miles 981-438	1	-	21	-	-	11	-	-	11	37	81
Miles 438-109[1]	52	103	38	-	-	1,564	4	4	-	165	1,930
Miles 109-0	25	59	245	4	4	17	-	40	8	79	481
Tributaries:											
Tennessee	62	-	-	37	-	34	-	-	1	62	196
Cumberland	-	-	-	-	-	7	-	-	-	4	11
Kanawha	26	22	10	-	-	127	14	1	-	215	415
Monongahela	1	53	141	7	-	18	23	188	-	48	479
Extrabasin	204	38	215	79	76	813	-	29	16		1,470
Total received	371	275	670	127	80	2,591	41	262	36	610	5,063

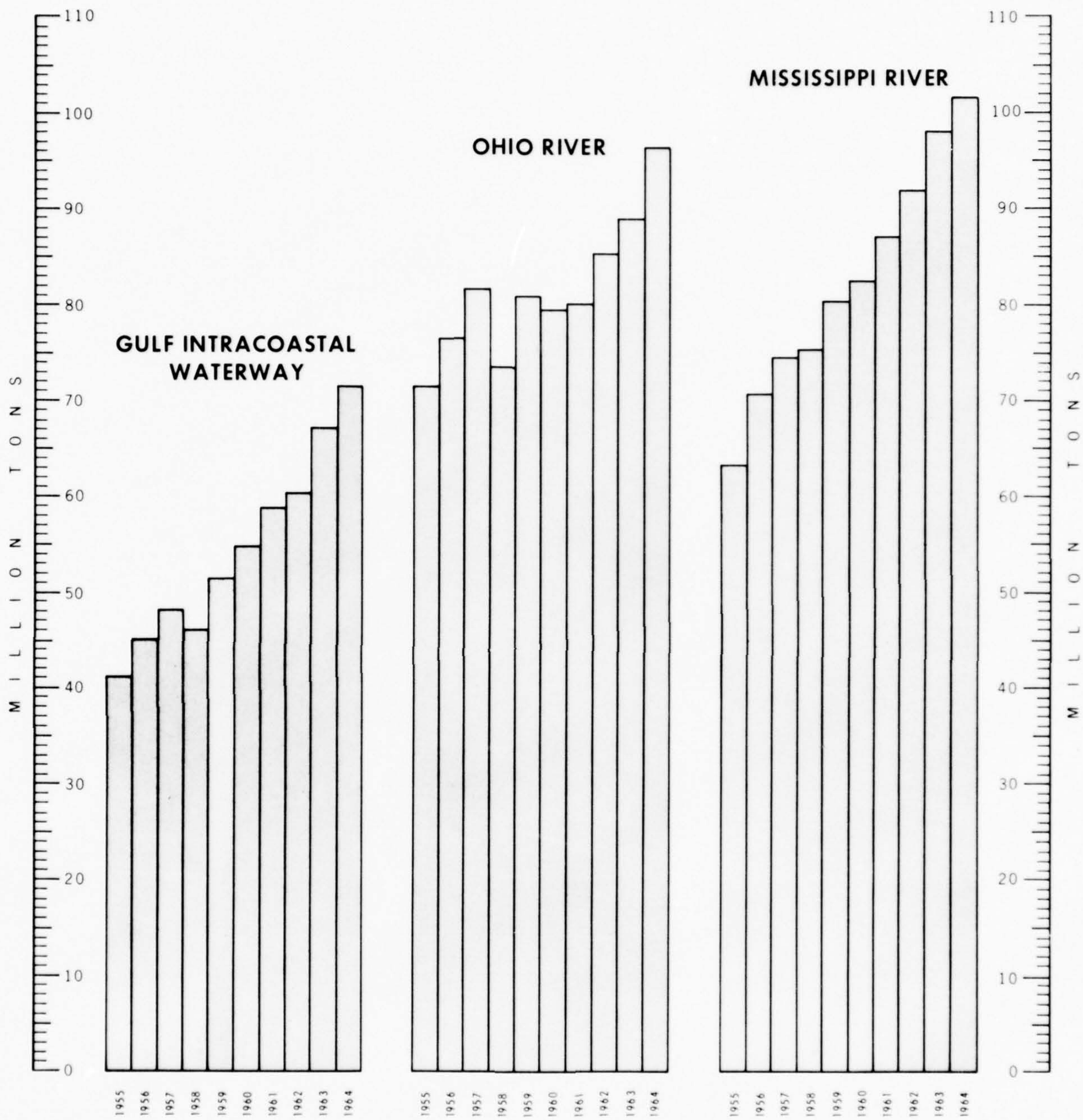
[1] Includes shipments of 120,000 tons from Big Sandy River.

TABLE 8. - IRON AND STEEL, AREA-TO-AREA WATER SHIPMENTS IN 1960, IN THOUSAND TONS

Origin area	Destination area										
	Ohio River main stem reaches			Tributaries							
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Tennessee	Cumberland	Kentucky	Kanawha	Monongahela	Allegheny	Extrabasin	Total shipped
Ohio River main stem reaches:											
Miles 981-438	6	9	141	1	6	-	-	13	21	60	265
Miles 438-109	49	-	5	5	-	-	-	11	146	110	326
Miles 109-0	274	34	40	42	13	-	1	42	11	928	1,385
Tributaries:											
Tennessee	-	-	16	-	-	-	-	3	5	15	39
Cumberland	1	2	22	-	-	-	-	1	-	2	28
Kentucky	-	-	-	-	-	1	-	-	-	-	1
Kanawha	-	-	6	-	-	-	-	1	1	1	9
Monongahela	329	12	15	33	15	1	1	758	9	547	1,720
Allegheny	-	-	-	6	-	-	-	1	-	14	21
Extrabasin	68	18	112	58	26	-	-	5	8		295
Total received	735	75	357	145	60	2	2	835	201	1,677	4,089

TABLE 9. - IRON AND STEEL, AREA-TO-AREA WATER SHIPMENTS IN 1964, IN THOUSAND TONS

Origin area	Destination area										
	Ohio River main stem reaches			Tributaries							
	Mile 981-Mile 438	Mile 438-Mile 109	Mile 109-Mile 0	Ten-nessee	Cumber-land	Kanawha	Little Kanawha	Monon-gahela	Alle-gheny	Extra-basin	Total shipped
Ohio River main stem reaches:											
Miles 981-438	2	15	93	-	7	-	-	2	1	34	154
Miles 438-109	53	-	5	-	16	-	-	1	108	113	296
Miles 109-0	335	29	76	29	33	1	-	10	1	708	1,222
Tributaries:											
Tennessee	2	-	7	3	-	-	-	-	9	36	57
Cumberland	1	2	22	-	-	-	-	-	-	-	25
Kanawha	-	-	2	-	-	-	-	-	1	-	3
Monongahela	315	7	23	15	3	-	4	941	22	392	1,722
Allegheny	-	-	-	11	-	-	-	1	-	2	14
Extrabasin	64	12	72	47	18	2	-	11	3		229
Total received	772	65	300	105	77	3	4	966	145	1,285	3,722



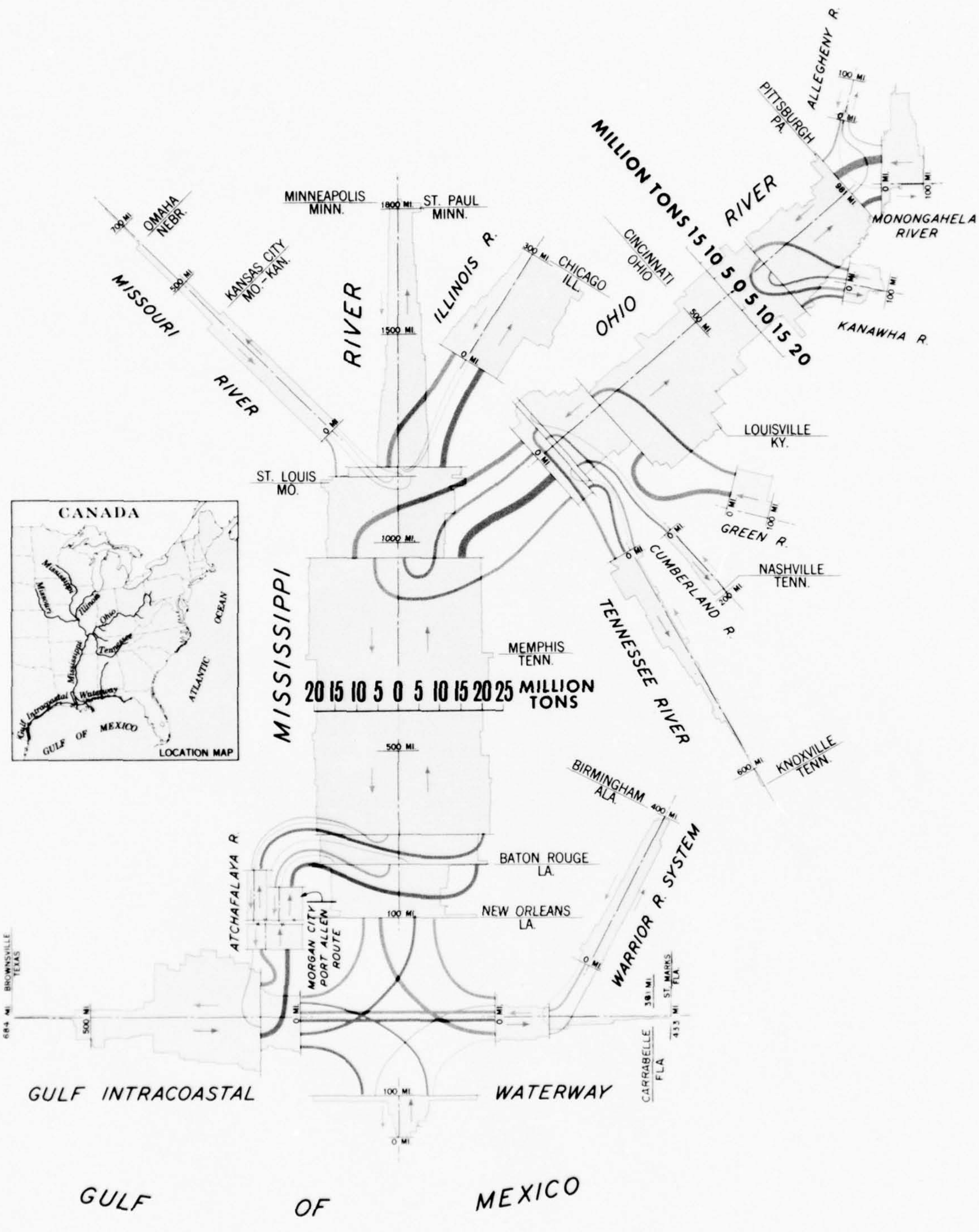
OHIO RIVER BASIN COMPREHENSIVE SURVEY

MISSISSIPPI RIVER, OHIO RIVER, AND G.I.W.W.
DOMESTIC FREIGHT TRANSPORT

COMPARISON OF ANNUAL TONNAGE, 1955-64

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 10



NOTE.— Maximum Kentucky River tonnage densities were 409,000 upbound and 53,000 downbound.

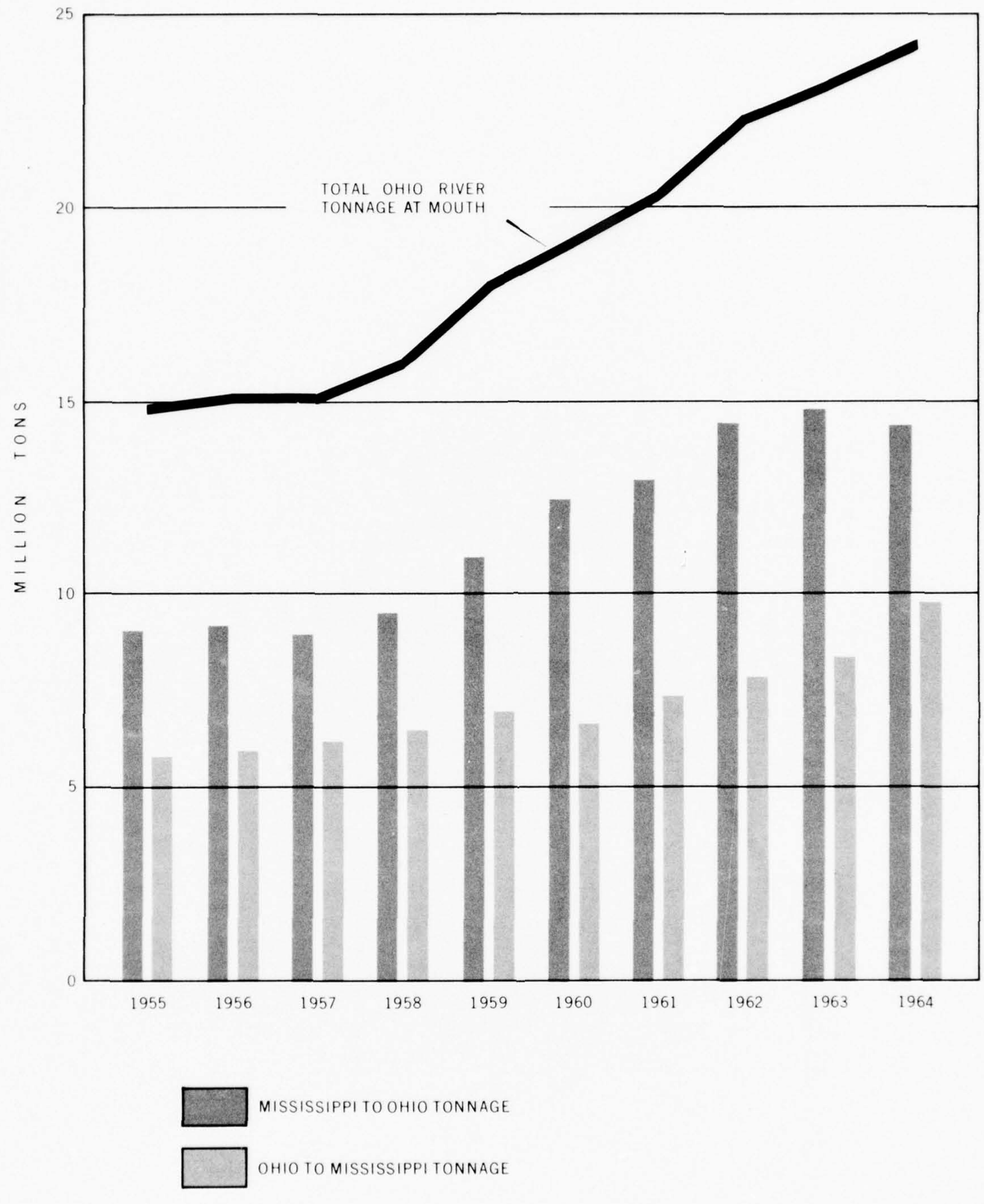
OHIO RIVER BASIN COMPREHENSIVE SURVEY

MISSISSIPPI RIVER SYSTEM AND GULF INTRACOASTAL WATERWAY

DOMESTIC TRAFFIC DENSITY, 1964

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

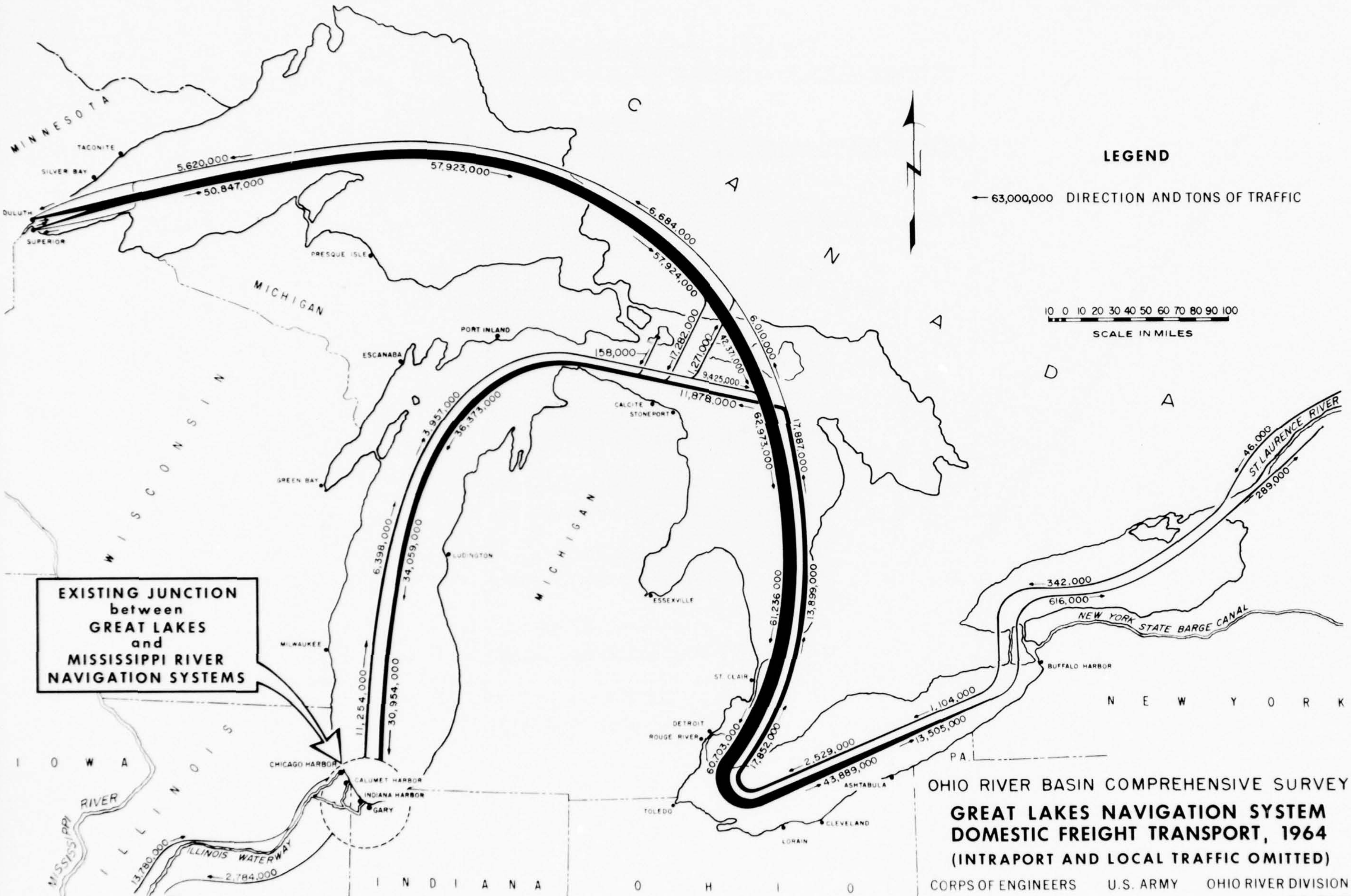
APPENDIX L FIGURE 11



OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO AND MISSISSIPPI RIVERS
FREIGHT TRAFFIC EXCHANGE, 1955 - 1964

CORPS OF ENGINEERS U. S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 12

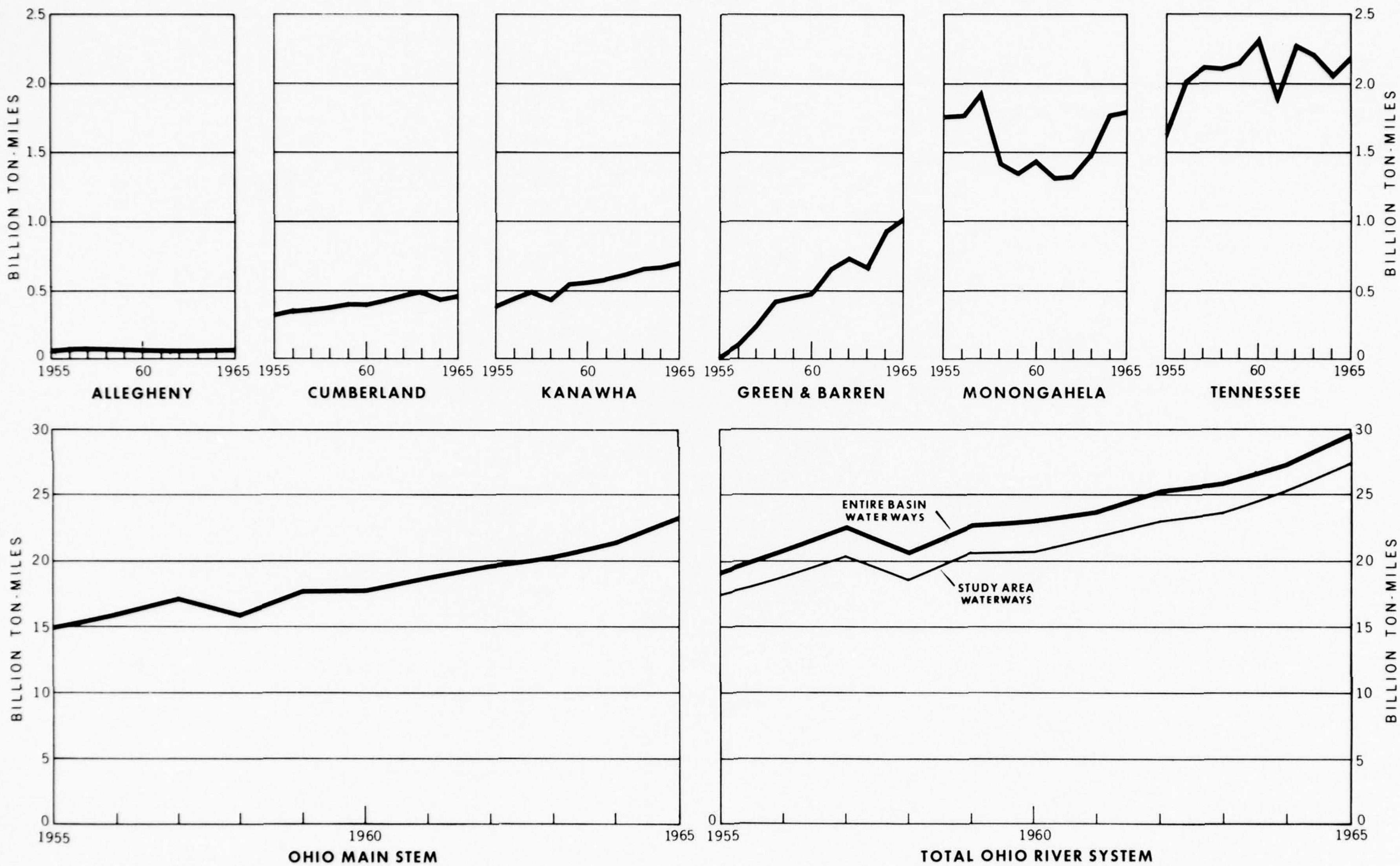


OHIO RIVER BASIN COMPREHENSIVE SURVEY

GREAT LAKES NAVIGATION SYSTEM
DOMESTIC FREIGHT TRANSPORT, 1964
(INTRAPORT AND LOCAL TRAFFIC OMITTED)

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 13

FIGURE 13

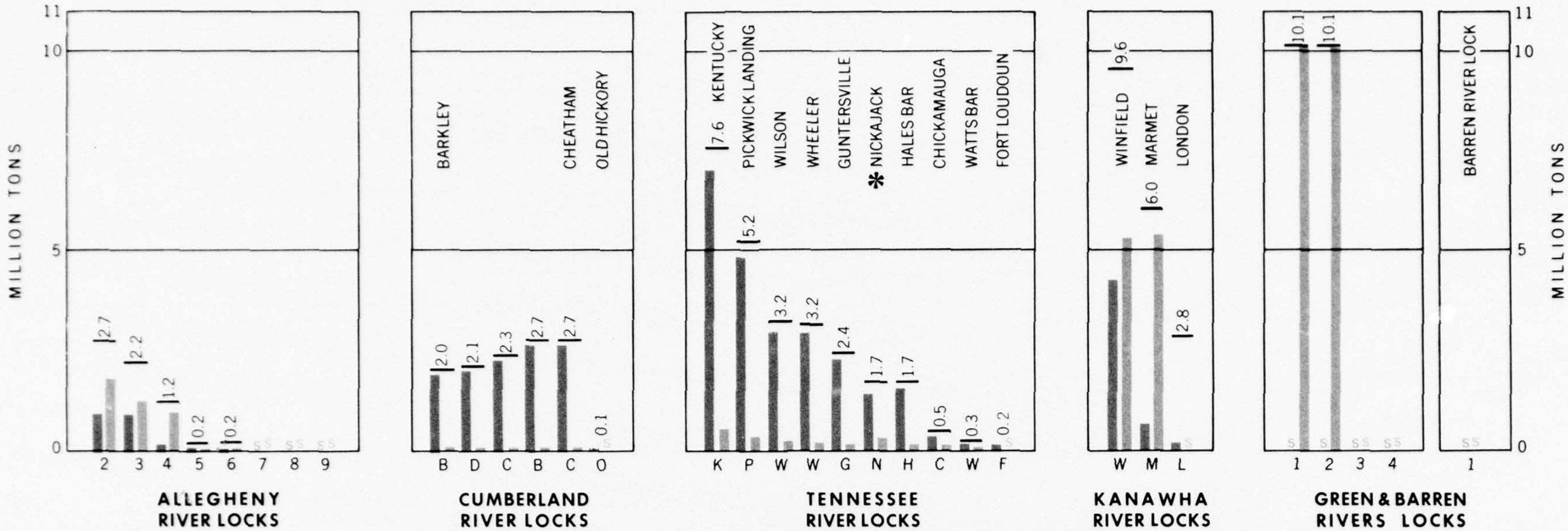


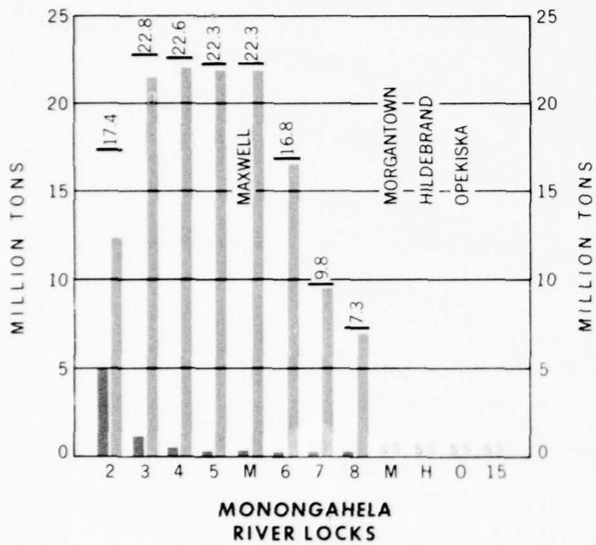
NOTE.— 1. Ton-miles for a waterway express how many miles each ton using the waterway moved on it. Ton-miles are therefore credited to the waterway reach on which they are accomplished.
2. Kentucky River annual ton-miles are less than 30 million.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

PRINCIPAL WATERWAYS - OHIO RIVER SYSTEM
ANNUAL TON - MILES, 1955 - 1965

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 14



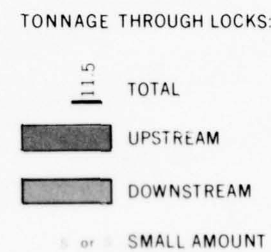


* Tonnage past lock site; lock not in operation.

NOTE.— 1. Tonnage passing the Ohio main stem locks in 1964 is shown, by direction, in figure 16.

2. Tonnage through the various Kentucky River locks is less than 0.41 million.

3. Recreational craft use all locks in the system.



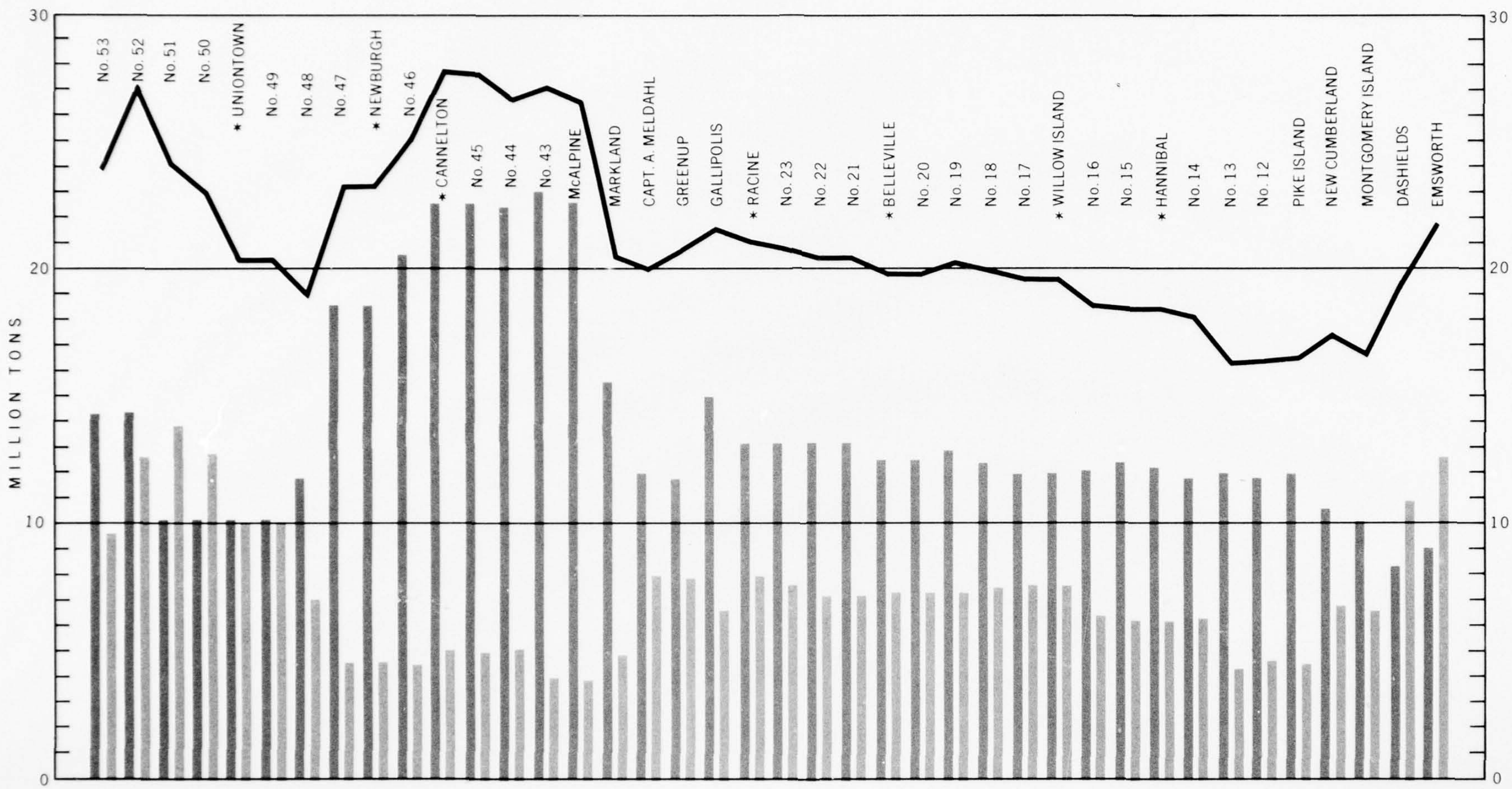
OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER TRIBUTARIES

TONNAGE DENSITIES AT THE LOCKS, 1964

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L **FIGURE 15**



TONNAGE THROUGH LOCKS:

TOTAL

UPSTREAM

DOWNSTREAM

* Tonnage past lock site; lock not in operation.

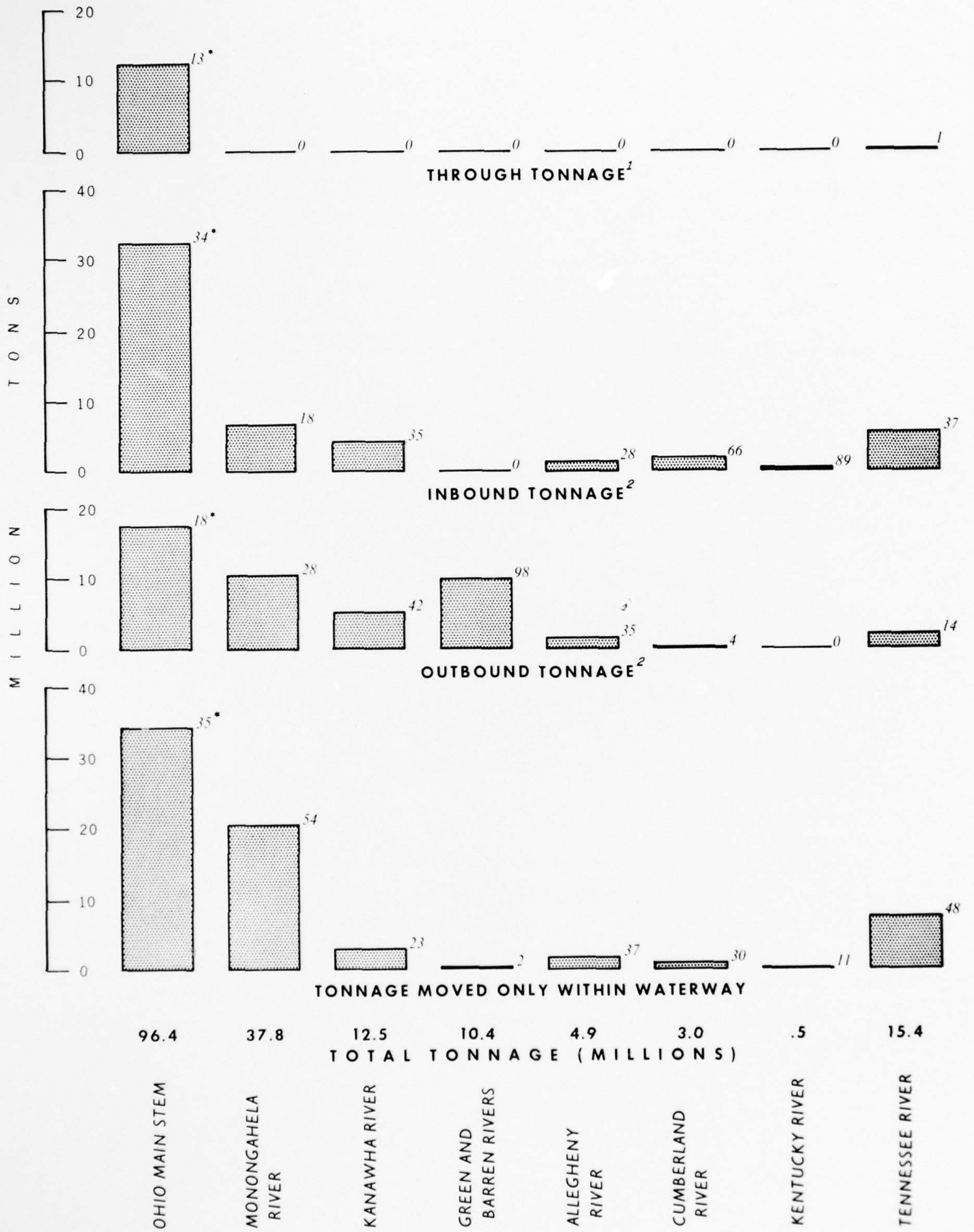
NOTE. – Recreational craft use all locks in the system.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO MAIN STEM TONNAGE DENSITIES, 1964
BY DIRECTION OF MOVEMENT
AT THE
LOCKS IN THE JULY 1965 PROGRAM

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 16



* Percent of total waterway tonnage.

[1] Originating (shipped) at and destined for points on connecting waterways.

[2] Tonnage moving from one waterway to another is "inbound" for the receiving waterway and "outbound" with respect to the waterway on which it originates.

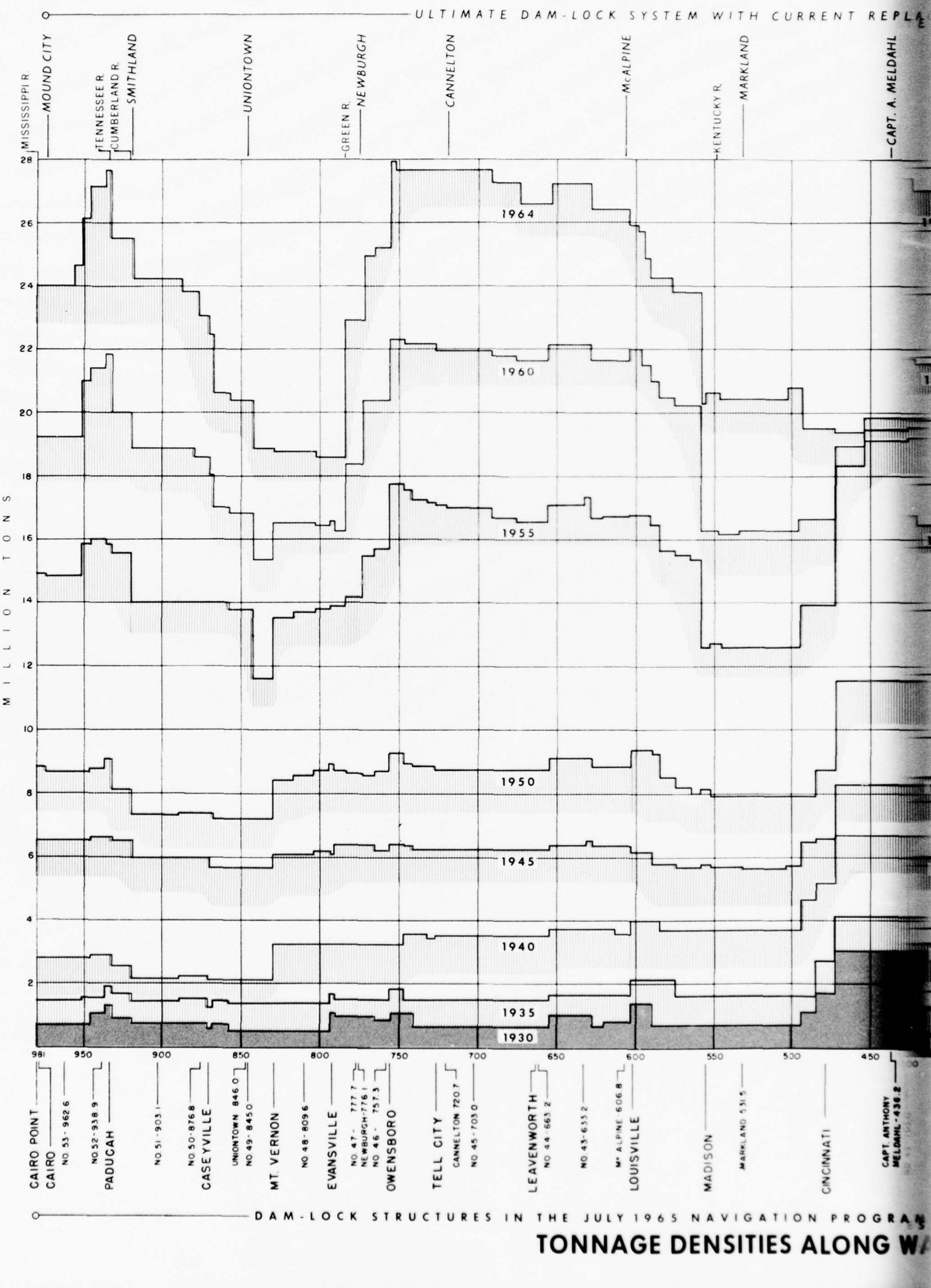
OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER SYSTEM FREIGHT TRAFFIC, 1964

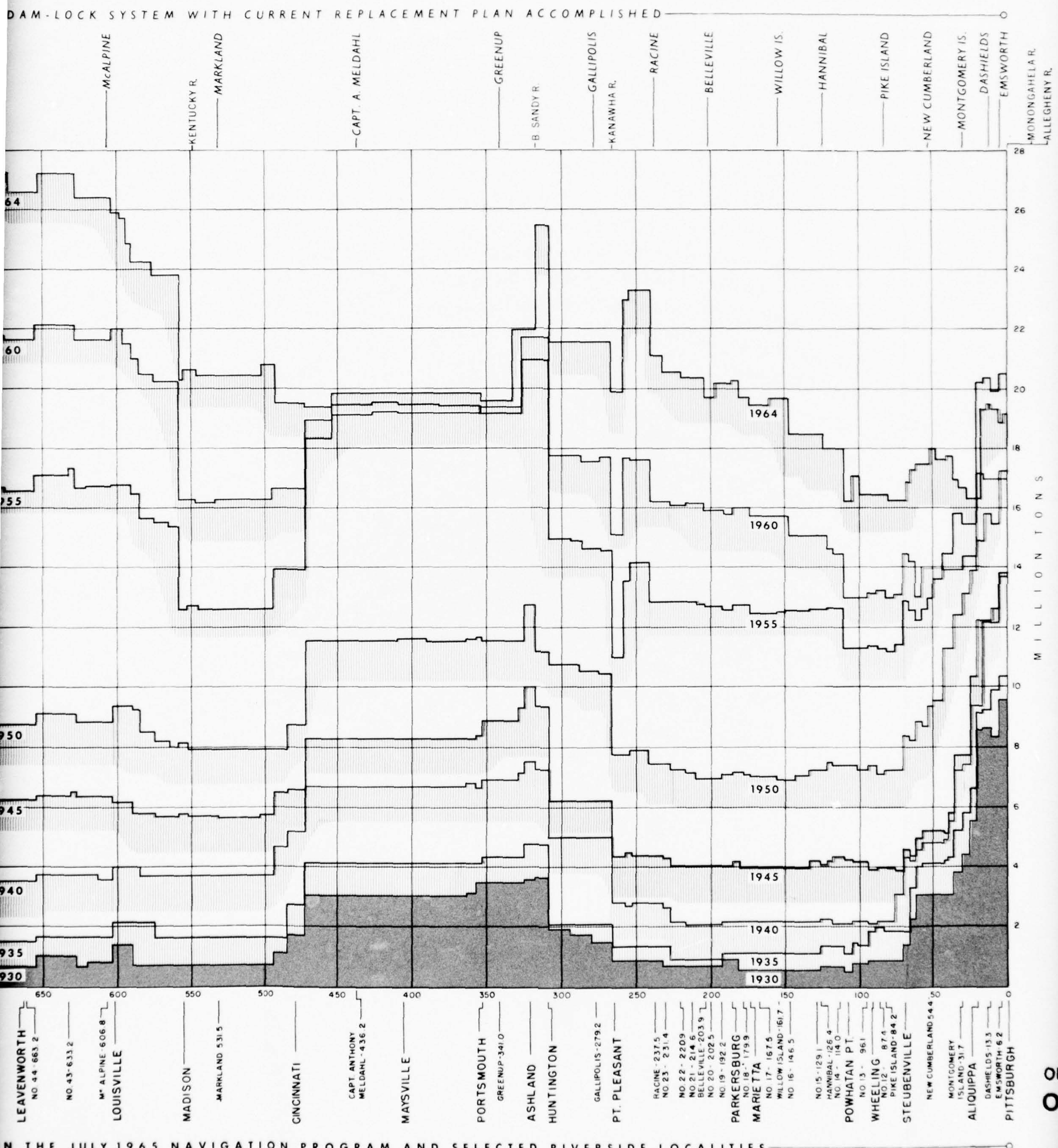
BY WATERWAYS AND ORIGIN-AND-DESTINATION CLASSES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 17



TONNAGE DENSITIES ALONG W



N THE JULY 1965 NAVIGATION PROGRAM AND SELECTED RIVERSIDE LOCALITIES

TONNAGE DENSITIES ALONG WATERWAY

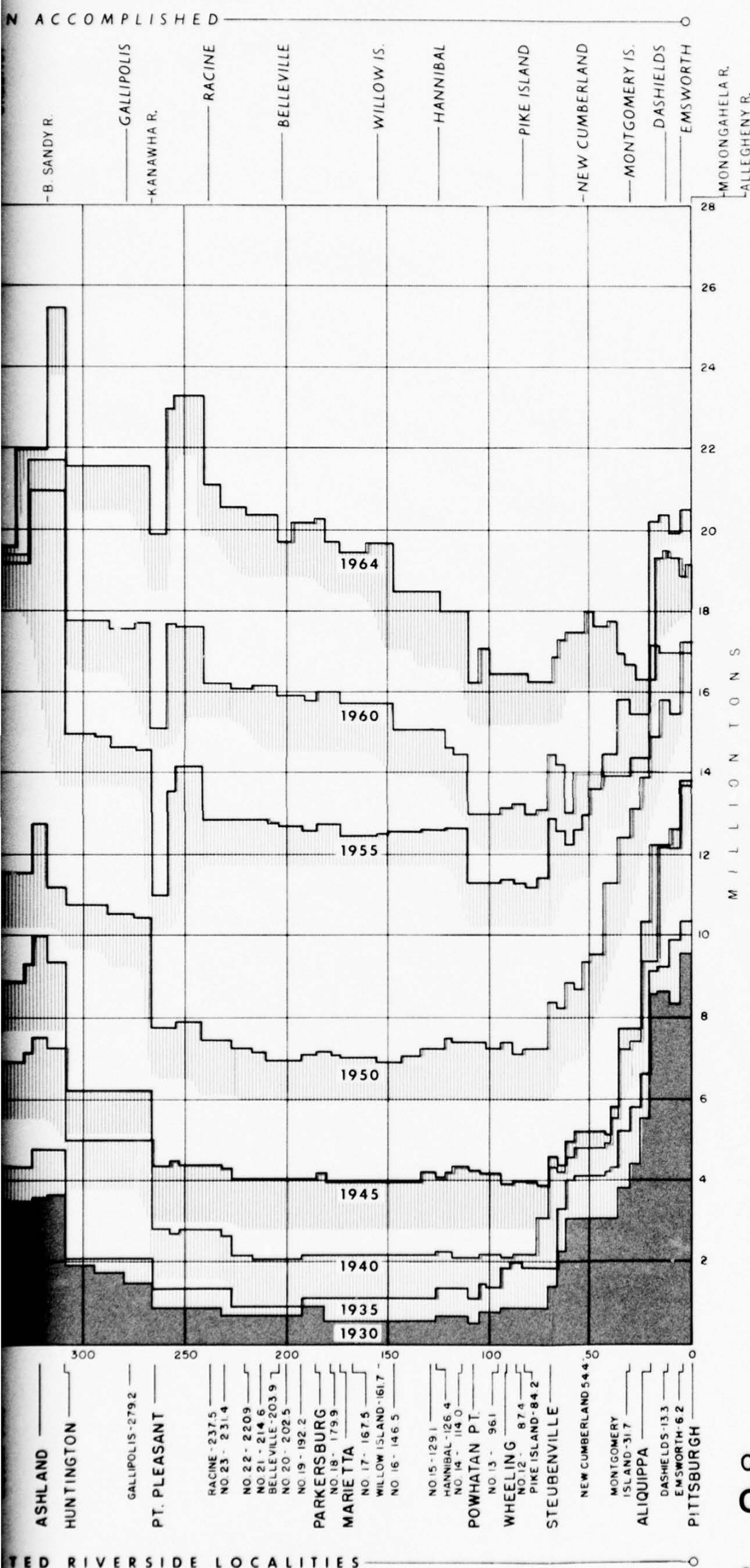
OHI

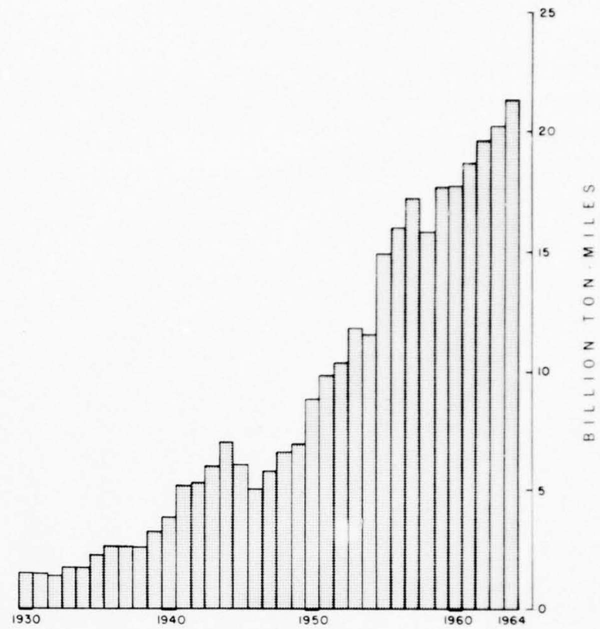
OH

CORI

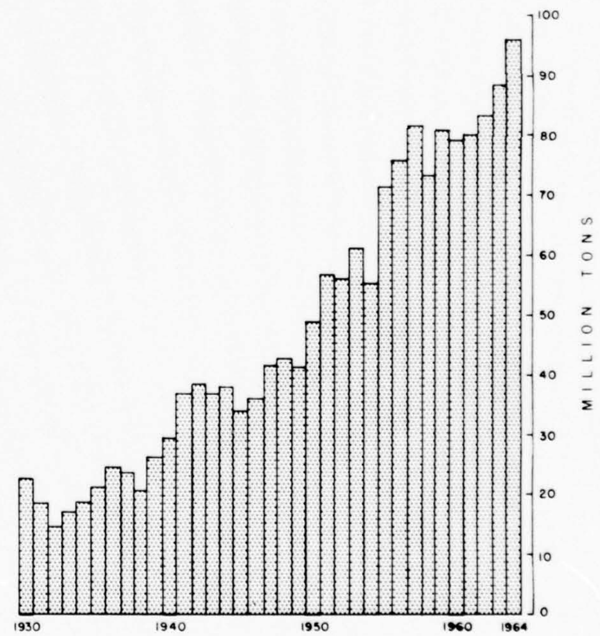
APP

2





ANNUAL TON-MILES



ANNUAL TONNAGE

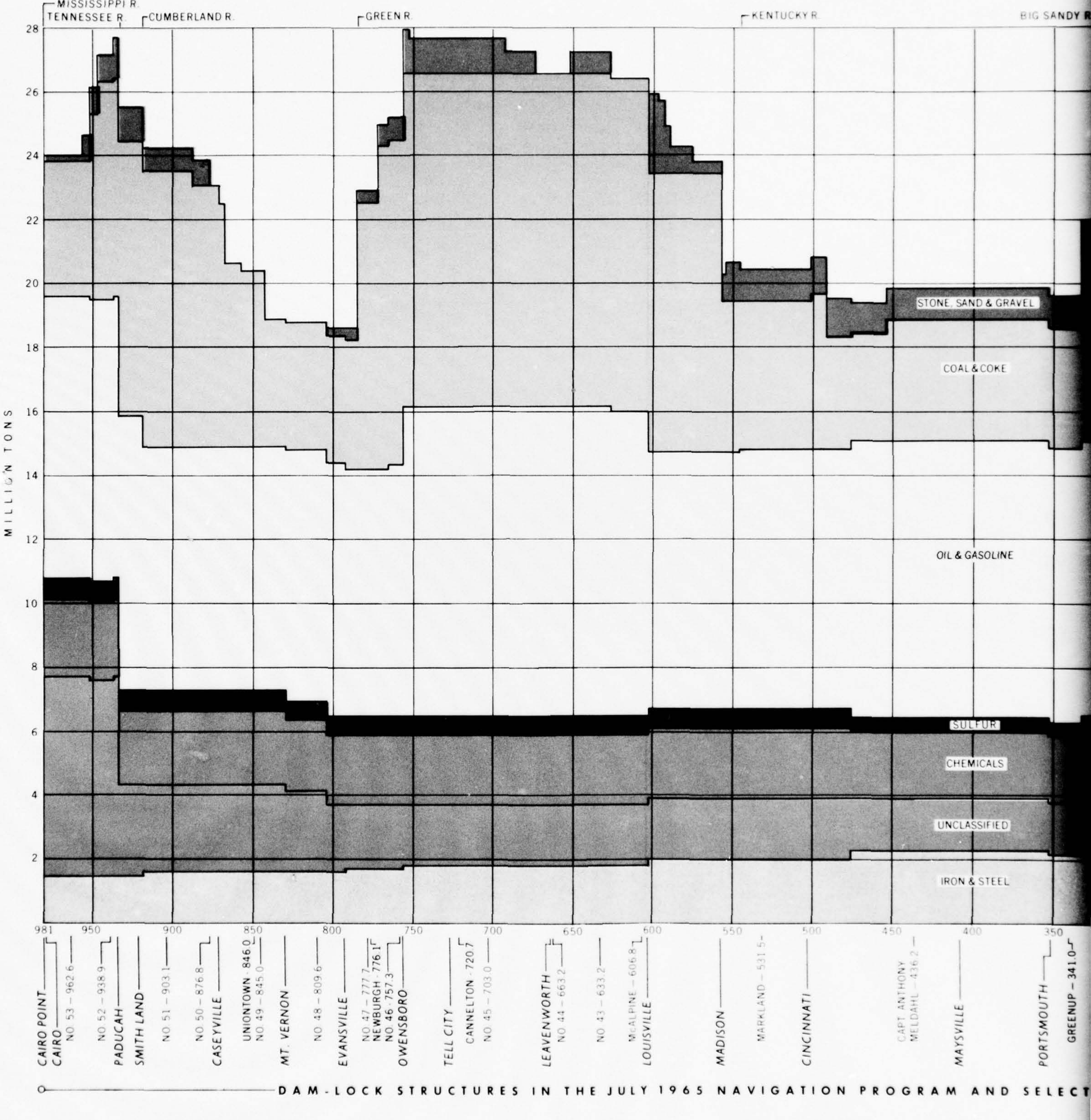
OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER FREIGHT TRAFFIC GROWTH 1930-1964

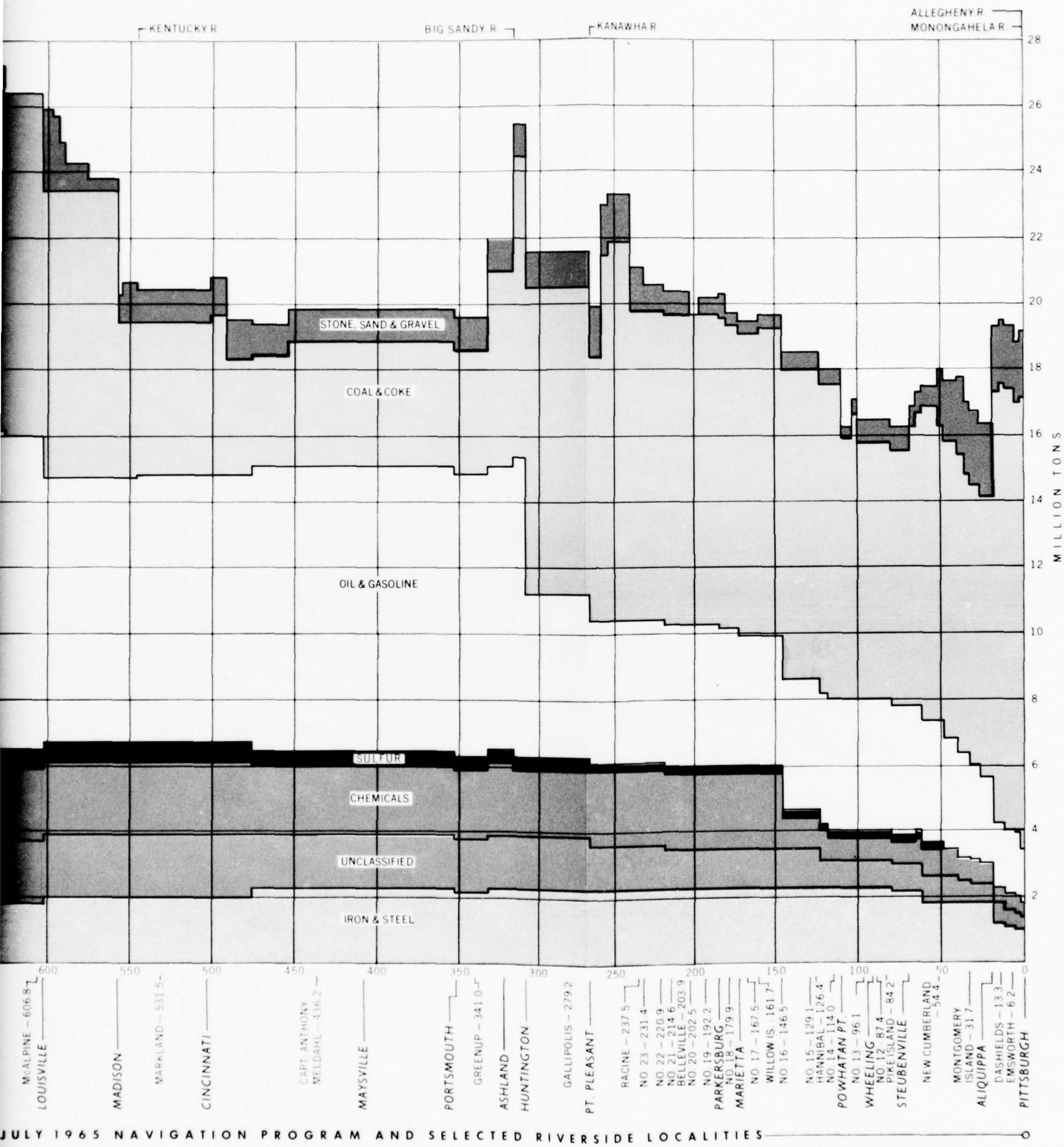
CORPS OF ENGINEERS U. S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 18

3



DAM-LOCK STRUCTURES IN THE JULY 1965 NAVIGATION PROGRAM AND SELECT



OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER TONNAGE DENSITIES, 1964

BY COMMODITIES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 19

B. PROJECTED GROSS DEMANDS FOR INLAND WATER TRANSPORTATION

The national transportation system is a crucial element in our total economy. Since 1958, the annual relationship of expenditures for transportation of one kind or another to our total expenses for goods and services (our Gross National Product) has been a relatively stable 20-21 percent. In the same period, the nation's estimated average annual freight bill was about 9.5 percent of the Gross National Product. The extent to which the several transport modes serve the needs of the economy's various sectors is a measure of their importance.

Intercity freight traffic experienced in the period 1950-60 a notable shift in the ton-mile proportions of the various modes, with river transport gaining considerably. From 1960 to 1964, the percentage changes were less pronounced. This development together with related data is portrayed in the following tabulation:

National Domestic Intercity Freight Traffic

Year	Total (billion ton-miles)	Percentage shares of the modes: Rails	Trucks	Oil pipe-lines	Great Lakes	Rivers and canals	Per capita share, rounded (ton-miles)
1950	1,094	57.4	15.8	11.8	10.2	4.8	7,000
1960	1,330	44.7	21.5	17.2	7.5	9.1	7,300
1964	1,549	43.8	22.6	17.4	6.9	9.3	8,000

By 1964, air freight movement had grown to only 0.1 percent of the intercity traffic.

A direct comparison of the cost of transporting goods by the different modes is very difficult because of the complex rate structures involved. The recent national freight rate averages following, however, indicate the general relationship:

Mode:	Freight revenue per ton-mile, in cents: 1960	1964
Air..........................	26.7	22.7
Motor carriers...............	6.0	6.1
Rails........................	1.4	1.3
Barges.......................	.3	.35
Pipelines....................	.3	.3

NOTE. - Source of national transportation data are "Statistical Abstract of the United States," U.S. Dept. of Commerce, 1967; Bureau of Mines, "Minerals Yearbook, 1965," Volume II: Mineral Fuels, U.S. Dept. of the Interior; and "Transportation: Facts & Trends," Transportation Association of America, April 1967.

Technological advances taking place to varied degrees in all transportation forms, as well as changes in institutional regulations and national policies, result in a shift in the cost, revenue, and tonnage relationships among the various modes. But since 1958, commerce on rivers and canals has been growing generally at very nearly the same rate as total national freight traffic.

Certain parts of the transportation needs are served best by waterways. Bulk raw materials and heavy commodities basic to agricultural and industrial production are frequently moved most economically by water. Transportation of coal and crude oil exemplifies the proportionately constant or, at times, increasing demand for waterborne movement of such commodities. Of the total U.S. production of bituminous coal and lignite (about 76 percent of which comes from the study area), the percent share shipped by water grew in 1950-60 from 5.3 to 11.3. By 1964 the share had increased to 12.2 percent, while in 1965 it declined slightly to 11.8 percent. Water transport's share of domestic crude oil deliveries to refineries for the 1960-65 period was a stable 15-16 percent. The availability of adequate waterways for the continually growing exchange of bulk-loading commodities is expected to result in a generally parallel growth of waterborne traffic.

The clustering characteristics of industries may contribute materially to the growth of inland navigation. The chemical industry especially appears to be gravitating to the large chemical complex, rather than small, dispersed plants. In such cases, the larger the operation, the more likely for water transportation to become economically desirable.

The continued growth of industry along the banks of the streams in the basin has been credited to a large degree for the healthy expansion of the water transport industry in the area. Major waterfront plant locations and expansions by production industry along the Ohio River averaged 43.5 units annually from 1955 through 1964. Average capital investments associated with such industrial growth were nearly $1.5 billion per year for the 15 years through 1964. Assuming this trend would continue to the year 2020, more than 2,000 additional plants would be built or expanded along the Ohio River with capital investments conservatively estimated at $69 billion, an increase of 314 percent over 1964. This projected development undoubtedly will spur the growth of navigation in the basin.

Whereas practically no first-class freight is now shipped by water, future demand for water transport of containerized goods appears to be substantial. A modernized river system and special vessels will allow higher speeds and a dependable schedule of movements, thus making waterborne shipments of high-value manufactured goods feasible. Terminal operations for such service have been organized. In addition, ocean-going cargo vessels which will carry preloaded barges in their hold are now under construction. Such barges could be integrated with regular tows on U.S. inland waterways and bring more of the latter's business into the sphere of world commerce. A comparable freight transport mode between the

Mississippi River system and the Great Lakes is being planned. Such novel services will expand the demand for river navigation and will sustain or possibly increase the proportionate share of unclassified commodities in future inland waterways traffic.

The capability to sustain its low-cost characteristics will shape the future of inland water transport. Any circumstance that would upset this marked feature could seriously affect the demand for this form of cargo movement. For example, the rate of growth of waterborne freight traffic might be altered by new institutional regulations or laws implementing changes in the national transportation policy. One aspect of the latter concerns ownership of the various modes of transportation. Common ownership of several modes is now prohibited by law, but some transportation interests contend that such ownership would eliminate many inhibiting factors which now lower intermodal efficiency. Opponents of intermodal ownership are convinced that it would destroy healthy competition which increases efficiency and keeps rates in line.

The projections of waterborne freight traffic in the Ohio River Basin are for estimating gross future needs in developing a framework plan for navigation, and they are the result of reasoned approximations and generalized relationships.[1]

The extent of detail considered and the degree of accuracy in the projections are in accordance with the framework study guidelines promulgated by the Water Resources Council. A detailed study of the basin's total transportation system would reveal a more precise outlook for waterborne commerce in terms of future relative competitive advantages among the transport modes due to changing technologies, volumes, distances, locations of markets and supplies, and numerous other transportation-economic factors. However, since such an overall basin transportation study was beyond the scope of the current survey, certain limiting conditions were necessary.

In general, future waterborne volumes were projected for the commodities which currently move by water, with the assumptions that, in the areas served by the waterway system, the growth of waterborne freight movement would be commensurate with the change in volumes moved by all other modes and today's general waterway traffic patterns would remain essentially the same. Furthermore, future waterway traffic, except for coal exports, was estimated within the framework of the subarea projections provided in "Appendix B: Projective Economic Study."[2] Projected water transport

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[1] The following part of the appendix covers only the survey's study area, which excludes the Tennessee River basin.

[2] The Ohio Basin was divided into 19 subareas for presentation of subregional economic data. A map of the areas is attached at back of that appendix.

of basin coal to outside areas was based on future coal output data given in Attachment B: Mineral Resource and Mining to "Appendix K: Development Program Formulation."

The methodology employed in deriving the gross demand for water transport in the subareas served by the navigation system, is contained in annex A to this appendix.

The projections for the Ohio River, its tributaries, and potential new waterways in the basin are covered in succeeding paragraphs and portrayed in figure 21.

1. Ohio River

With no extensions to the basin waterways system built beyond the project limits of the 1965 program, annual tonnage on the Ohio River is projected to increase nearly six times, from 79.5 million in 1960 to 467 million by 2020. Associated ton-miles will increase from 17.7 billion to 117 billion - more than 6.5-fold. Respective average annual growth rates for tonnage and ton-miles, over the 60-year interval, are 3.0 and 3.2 percent.

Five general commodity groups - coal and coke; petroleum and its refined products; stone, sand, and gravel; chemicals and sulfur; and iron and steel - account for nearly 92 percent of the current, total river tonnage. The remainder consists of goods assigned to the category "Unclassified." Table 10 presents past freight traffic data together with projections for the six commodity groups. The sums of these latter for the years 1980, 2000, and 2020, give the estimated total future annual water transport demand on the Ohio River. The projected traffic development is shown graphically in figure 20.

TABLE 10. - DEMAND FOR FREIGHT TRANSPORTATION ON THE OHIO RIVER WITH NO EXTENSIONS TO THE BASIN WATERWAYS SYSTEM BEYOND 1965 PROGRAM

Commodity group	Demand for waterborne transport: Actual 1960	Actual 1964	Projected 1980	Projected 2000	Projected 2020
Coal and coke:					
Tons, million	39.9	46.7	75.0	137.0	233.0
Ton-miles, billion	6.0	7.4	15.0	29.0	50.0
Petroleum and refined products:					
Tons, million	16.3	19.1	35.0	56.0	100.0
Ton-miles, billion	6.0	7.0	13.0	22.0	39.0
Stone, sand, and gravel:					
Tons, million	10.1	14.4	19.0	32.0	56.0
Ton-miles, billion	0.3	0.8	1.0	1.7	3.0
Chemicals and sulfur:					
Tons, million	3.8	5.7	9.7	18.0	33.0
Ton-miles, billion	1.6	2.4	3.4	5.9	11.0
Iron and steel:					
Tons, million	3.7	2.9	4.3	5.4	7.6
Ton-miles, billion	2.4	1.9	2.8	3.5	4.8
Unclassified:					
Tons, million	5.6	7.6	16.0	28.0	37.0
Ton-miles, billion	1.2	1.9	3.8	6.8	9.3
Total:					
Tons, million	79.5	96.4	159.0	276.0	467.0
Ton-miles, billion	17.7	21.3	39.0	69.0	117.0
Ton-miles per river mile, million	18.0	21.7	40.0	70.0	119.0

Construction of potential basin and interbasin extensions to the Ohio River system needed to serve the projected demands would result in additional traffic on the main stem. With all such potential waterways progressively completed as required, increased water transport demands on the Ohio are expected to grow as follows:

Projected Ohio River total traffic

Item	Year: 1980	2000	2020
Tons, million	182	329	531
Ton-miles, billion	42	76	127
Ton-miles per river mile, million	43	77	130

This development of freight traffic demand represents an average annual tonnage and ton-mile growth rate of 3.2 and 3.3 percent, respectively, over the base year traffic of 1960. The 1960-to-2020 tonnage and ton-mile increases will be 6.7- and 7.2-fold.

a. Coal. - In 1960 the Ohio River Basin supplied about 76 percent of the total United States bituminous coal output, about 86 percent of which was exported from the basin to areas throughout the Eastern United States and overseas. The basin coal output is expected to increase about 8.7 times, from 317 million tons in 1960 to about 2.76 billion in 2020. Correspondent coal production in the basin subareas with impact on Ohio River coal movement is projected to increase about 6.2 times. The following tabulation shows past and projected coal production in those subareas. Projections are based on data presented in appendices B and K.

	Total coal production, in million tons			
	1960	1980	2000	2020
Ohio Basin subareas:				
A - Allegheny	21.5	54	96	190
B - Monongahela	44.4	95	139	219
C - Pittsburgh SMSA	20.0	46	73	129
E - Upper Ohio	15.8	50	104	241
G - Kanawha-Little Kanawha	36.4	72	104	150
H - Ohio-Huntington	2.6	10	22	55
J - Guyandotte-Big Sandy-Little Sandy	76.5	140	181	189
O - Lower Ohio-Evansville	14.0	53	123	303
P - Green	25.3	54	77	119

Basis for estimates of future coal traffic on the Ohio River are the 1960 area-to-area coal movements presented in table 2.

The main sources of coal transported on the Ohio are from river traffic originating on the Allegheny, Monongahela, Kanawha, and Green River tributary waterways and volumes from inland areas loaded on barges at Ohio main stem points. About 80 percent of the coal moved on the Ohio is terminated on that river, and the greatest part of this is used at river ports and by industrial plants on or near the waterway. Major users are steam-electric generating plants and the primary metals and chemicals industries. The remaining Ohio River coal tonnage is divided in two approximately equal parts, one destined for points on the tributaries, and the other, via the Mississippi, for areas outside the basin.

Projections of Ohio River coal traffic are determined from estimates of future demands for coal in and outside the study area. Evaluation of demands in the various basin subareas is based on data contained in "Appendix B: Projective Economic Study." Estimates of extrabasin needs are based on the above-tabulated future subarea coal production. The demand for basin coal by the electric power industry in and outside the study area, is projected to increase nearly nine times in the period 1960-2020.

Corresponding demands by industries other than the electric generating are estimated to increase three times. Total demand for coal in the areas which are served by waterways is projected to grow about 7-fold from 1960 to 2020. This future demand, however, includes the needs of mine-mouth electric generating plants, for which little or no water transport is likely.

Movement of coal and coke on the Ohio main stem is projected to increase from 39.9 million tons in 1960 to 233 million in 2020, or about 5.8 times. Associated ton-miles will grow 8.3-fold, from 6 billion to 50 billion.

b. Petroleum and refined products. - In 1960 the Ohio Basin produced crude oil volumes which approximated those used by the basin refining industry. However, because of location of points of supply and demand, ownership, and quality requirements, part of the basin oil is shipped outside the region, while some petroleum tonnage is imported into the basin. Nearly 40 percent of the refined petroleum products used in 1960 in the study area, were imports.

Estimates of future movements of petroleum and its products on the Ohio River are based on the 1960 area-to-area traffic presented in table 4. Of the 16.2 million tons carried that year on the Ohio River, 8.2 million were intrabasin movements of crude oil and refined products. Of the remaining tonnage, 7.2 million were imported, and 0.8 million, exported. Half of the peak shipments originating in the Ohio River reach, miles 981-438, consisted of crude oil to the Ohio River reach, miles 438-109 - largely to docks which serve the refining industry near the mouth of the Big Sandy River. The major industry users of petroleum products besides petroleum refining itself, include chemicals, construction, and transportation. The household sector is also a major user, accounting for about 45 percent of the total basin demand for refined products.

In the future, the study area is expected to continue to be a net importer of petroleum products and crude oil. Total basin demands for these are projected to increase by 2020 about 8.7-fold over the 1960 volumes.

Projections of Ohio River petroleum and allied products traffic show an increase of about 6.1 times, from 16.3 million tons in 1960 to about 100 million by 2020. Associated ton-miles will grow 6.5-fold, from 6 billion to 39 billion.

c. Stone, sand, and gravel. - In 1960 the Ohio River Basin produced about 126.4 million tons of stone, sand, and gravel. This was about 16 percent of the total basin output in dollars of the mining industries other than coal.

Movements of stone, sand, and gravel are essentially shorthaul, as supplies are available throughout much of the Ohio River system. The average haul has been around 40 to 50 miles. Estimates of future traffic are based on the 1960 tonnage. Shipments, in that year, to points along the Ohio main stem amounted to about 8 million tons, and those outbound from the Ohio to various tributaries, 2.3 million. Major users, consuming about 74 percent of the total output, are the construction and stone and clay products industries, which include cement manufacturing.

The demand for stone, sand, and gravel is projected to increase in the period 1960-2020, at rates varying from 4.5 times in the Pittsburgh area to about 10 times in the Licking-Kentucky-Salt basin area. Projections of stone, sand, and gravel tonnage moving on the Ohio River show a 5.5-fold increase from 10.1 million in 1960 to around 56 million by 2020. Associated ton-mile growth is expected to be about 10-fold, reaching 3 billion.

d. Chemicals and sulfur. - The Ohio River Basin produced about 13 percent of the total U.S. chemicals dollar output in 1960. About 40 percent of the basin's current chemicals dollar output is in sulfuric acid, alcohols, coal tar, and other basic industrial products. Plastics, synthetic resins, and man-made fibers account for about 20 percent, while drugs, cleaning and toilet goods, paints, gum and wood chemicals, and agricultural as well as miscellaneous goods make up the remainder. In general, the basin is a net exporter of chemicals, about 6 percent of the total output being shipped to points outside the region.

All sulfur is imported into the basin. In 1960, sulfur constituted 11.2 percent of the Ohio main stem commerce in commodities of the general grouping "Chemicals and sulfur."

Future waterborne movements of commodities in this grouping are projected on the basis of the 1960 area-to-area traffic shown in table 6. A large part of the shipments originate in the Ohio River reach, miles 438-109, and most of these volumes move to the industrial complex in the Kanawha River Valley. The chemical industry is its own best customer using about 25 percent of its gross output. The demand for chemicals is spread throughout the industry structure. Sulfur is used for producing sulfuric acid in plants located along the Ohio and the Kanawha Rivers. Part of the sulfur moving on the Upper Ohio River is transshipped to rail in the Pittsburgh area for final destination in Eastern States and Canada.

Ohio River Basin chemicals output is projected to increase by 2020 about 8.7-fold over the 1960 volumes. Correspondent output in the Kanawha-Little Kanawha area is expected to grow about 7.5 times. The Ohio main stem and the Kanawha River around Charleston will most likely continue to be major destination and shipping areas for waterborne commerce in chemicals and sulfur.

By 2020, it is estimated that about 33 million tons of chemicals and sulfur will move on the Ohio River main stem - about 8.7 times more than

in 1960. Associated ton-miles will increase close to 6.9 times to nearly 11 billion.

e. Iron and steel. - The Ohio River Basin produced in 1960 about 31 percent of the Nation's steel output or about 31 million tons. About two-thirds of this tonnage came from the industry in the Pittsburgh-Steubenville-Weirton area along the Ohio, Monongahela, and Allegheny Rivers.

The basin iron and steel output as projected to 2020 shows an increase over 1960 volumes of about two times, but this is expected to represent a diminished share of 21 percent of the total United States steel output. Since more of the basin's iron and steel production is expected to be used within the area than in the past, projected exports are estimated to decline from about 11.6 million tons in 1960 to 3.5 million in 2020.

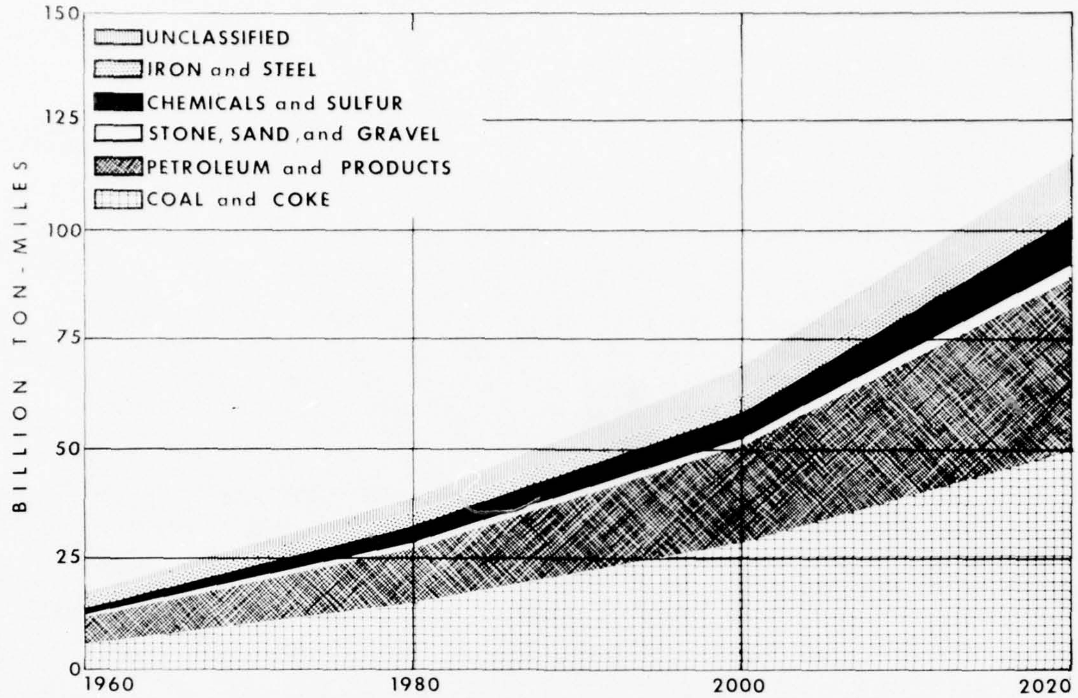
Basis for estimates of future iron and steel traffic on the Ohio River are the 1960 area-to-area movements presented in table 8. About three-fourths of the iron and steel volumes moving on the Ohio main stem come from the Pittsburgh, Monongahela, and Allegheny areas; about one-fifth are terminated there; and about one-half are exports to docks outside the study area. About 10 percent of the Ohio River iron and steel traffic is imports from outside the basin consisting mostly of scrap iron.

Projected iron and steel traffic on the Ohio main stem is expected to reach about 7.6 million tons and 4.8 billion ton-miles by 2020 - a two-fold increase over the respective 1960 figures.

f. Unclassified. - Commodities in this group include a variety of goods ranging from foodstuffs to heavy machinery. In 1960, those with significant tonnage on the Ohio were nonferrous metals and ores, slag and metal refuse, nonmetallic minerals, and building cement. Grains accounted for about 2 million of the 5.6 million tons of unclassified commodities.

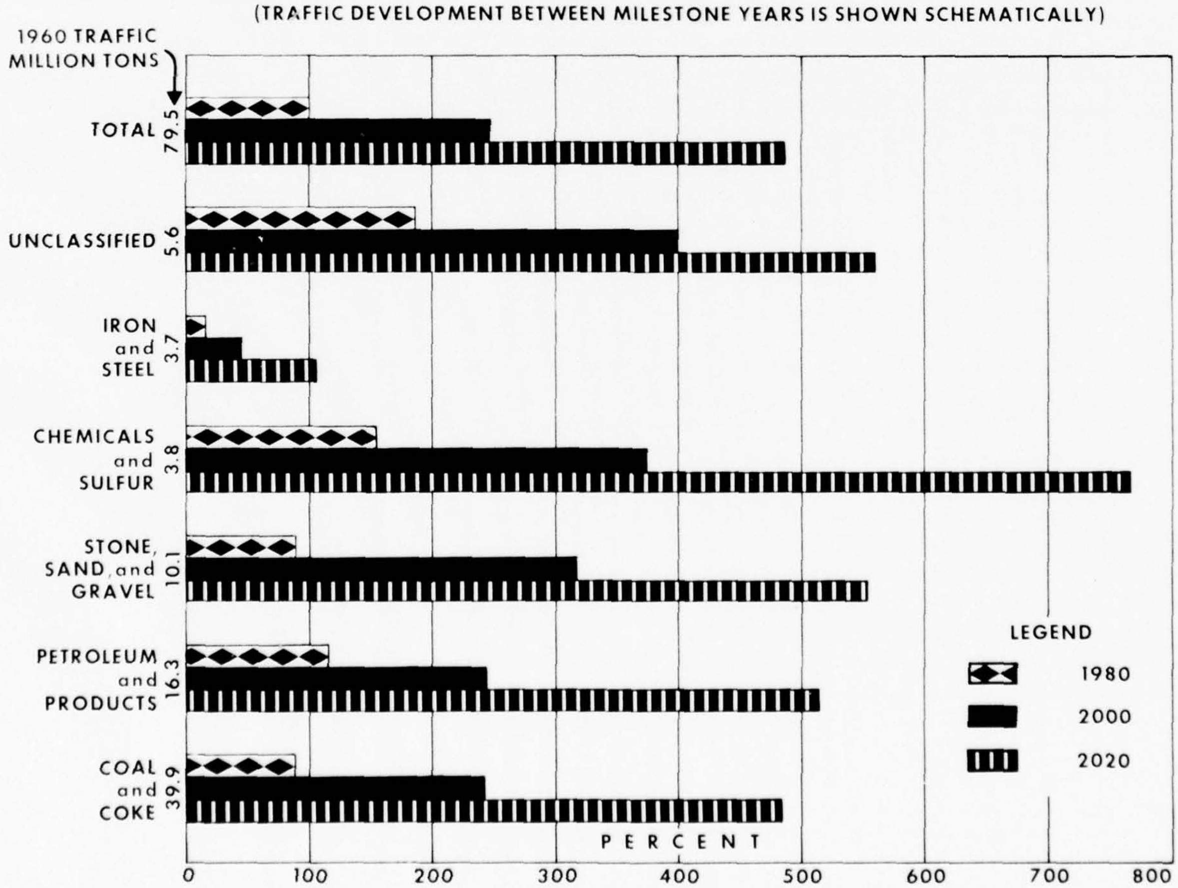
Roughly three-fourths of the 1960 grains traffic on the Ohio originated outside the study area's waterways system. About 85 percent of the river's total grains tonnage moved via the Tennessee to markets in the Southeast. Less than 4 percent of the grains volumes were shipped from or received at points upstream from Evansville, Ind. Grains traffic originating on the Ohio main stem came from the Lower Ohio-Evansville subarea and mostly moved downstream onto the Tennessee River or the Mississippi. It is expected that about 6.5 million tons of grains would move by 2020 on the Ohio.

Future traffic was estimated in toto for unclassified commodities. Based on a time series projection, 1960 tonnage will increase 6.6-fold to about 37 million by 2020, and associated ton-miles, 7.8-fold to 9.3 billion.



PROJECTED OHIO RIVER TON-MILES, 1980 — 2000 — 2020

(TRAFFIC DEVELOPMENT BETWEEN MILESTONE YEARS IS SHOWN SCHEMATICALLY)



PROJECTED PERCENT INCREASE OF OHIO RIVER TONNAGE (BASE, 1960 TRAFFIC)

OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER TRAFFIC - PROJECTED GROWTH

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 20

2. Major canalized tributaries

Each tributary, though an integral part of the overall system, has special factors which have influenced its commerce. For example, the majority of movements on the Monongahela and Allegheny Rivers have been most significantly affected by the steel industry, while the Kanawha traffic has changed with the area's chemical production and the steamelectric generation in the Ohio Basin.

Future tonnage for each tributary is projected in toto. Estimates are based on the 1960 traffic pattern and expected changes in demand for the most important commodities which the various waterways now carry. Particular factors of import to river commerce on some of the tributaries such as the projected growth of certain industries, are considered. As a result, tonnage increases by 2020 are estimated to vary in the range from 1.8 to 8.4 times the 1960 volumes. The lowest growth rate is projected for the Monongahela River, and the highest one, for the Green. These rates mirror, respectively, the moderate growth forecast for the primary steel industry and the substantial expansion expected for coal-fired steamelectric generation along the Ohio River. Table II presents for each major tributary in the study area, actual and projected total freight traffic.

TABLE 11. - DEMAND FOR FREIGHT TRANSPORTATION ON MAJOR IMPROVED OHIO RIVER TRIBUTARIES

	Actual		Projected		
	1960	1964	1980	2000	2020
Tributary:					
Kanawha River:					
Tons, million	10.1	12.5	24.8	50.5	78.0
Ton-miles, billion	.558	.671	1.4	2.7	4.2
Ton-miles per mile, million	6.2	7.4	14.8	30.1	46.4
Monongahela River:					
Tons, million	29.5	37.8	40.0	46.0	53.0
Ton-miles, billion	1.421	1.772	1.9	2.2	2.5
Ton-miles per mile, million	11.0	13.8	14.6	16.8	19.4
Green and Barren Rivers:					
Tons, million	5.4	10.4	20.7	35.1	45.0
Ton-miles, billion	.471	.928	1.9	3.2	4.1
Ton-miles per mile, million	2.6	5.2	10.3	17.5	22.5
Cumberland River:					
Tons, million	2.8	3.0	5.5	10.9	20.1
Ton-miles, billion	.397	.435	.8	1.7	3.2
Ton-miles per mile, million	1.3	1.4	2.1*	3.0**	5.7**
Allegheny River:					
Tons, million	3.8	4.9	6.0	8.0	10.5
Ton-miles, billion	.058	.057	.07	.10	.13
Ton-miles per mile, million	.8	.8	1.0	1.3	1.7
Kentucky River:					
Tons, million	.4	.5	.9	1.8	3.2
Ton-miles, billion	.028	.030	.06	.12	.21
Ton-miles per mile, million	.1	.1	.2	.5	.8
Total ton-miles (rounded), all tributaries, billion	2.9	3.9	6.1	10.0	14.3

* With the navigation project extended to Celina, Tenn.

** With the navigation project extended to Laurel River's mouth.

3. Potential new waterways

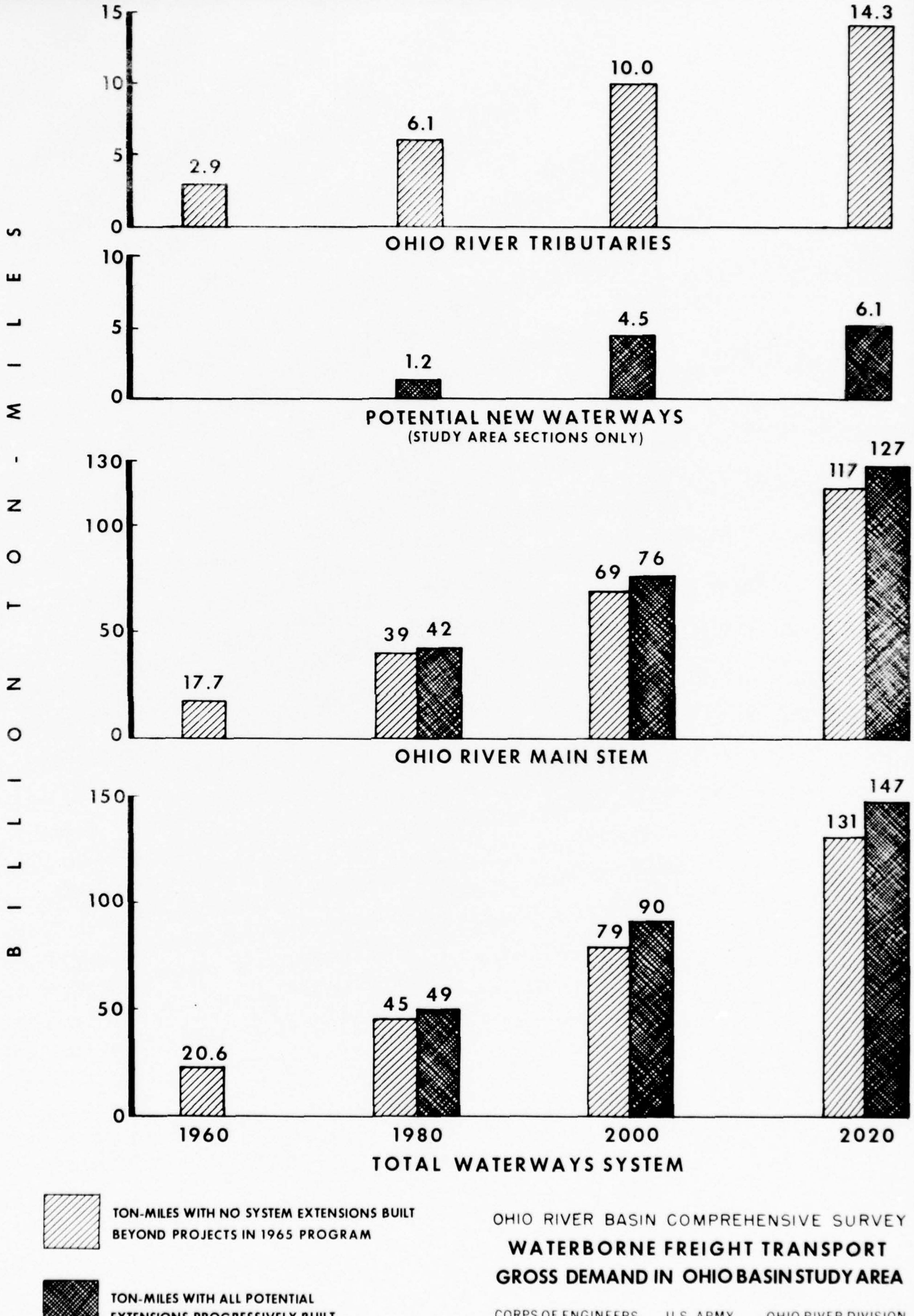
Potential waterways in the study area are the Lake Erie-Ohio River Canal and the canalized Big Sandy and Wabash Rivers. Estimates of waterborne commerce along these waterroutes, based on recent detailed studies, are presented in table 12. Wabash River traffic projections are for a

135-mile canalized waterway from Ohio River to Terre Haute, Ind. In addition, need for low-cost water transport of bulk commodities extends to the Great Lakes, beyond the Wabash River basin divide. Potential solutions concerning an interregional waterway connecting a canalized Wabash River with Lake Michigan and/or Lake Erie are now under preliminary study but not included in the framework plan and the development program.

Additional demand for waterborne freight transport exists along other tributaries, in particular the Saline, White, Great Miami, Licking, Little Miami, Scioto, Little Kanawha, and Muskingum Rivers. White River area needs would be partly served by or in conjunction with the potential Wabash River canalization. Regarding the Muskingum River, a current comprehensive study for developing the water and related land resources in its watershed will include an evaluation of the needs for both freight and recreational navigation on the stream. Needs in the areas adjoining the channel reaches of the listed tributaries into which extends slack water from the new Ohio River navigation pools are included in the Ohio River projections. Concerning the embayment created on Saline River, demand for water transport was estimated in a recent detailed study to grow from 6 to 9 million annual ton-miles over the period 1980-2020. Associated projected tonnage growth was from 0.9 million to 1.2 million. Past investigations have indicated no practical solutions to meet foreseeable needs on these tributaries upstream of the Ohio River backwaters.

TABLE 12. - DEMAND FOR FREIGHT TRANSPORTATION ON POTENTIAL NEW WATERWAYS

Waterway:	1980	2000	2020
Lake Erie-Ohio River Canal (61-mile Ohio Basin section):			
Tons, million	10.0	52.0	59.0
Ton-miles, billion	.6	3.1	3.5
Ton-miles per mile, million	8.6	44.6	50.6
Big Sandy River-Levisa Fork:			
Tons, million	6.0	10.8	15.6
Ton-miles, billion	.25	.45	.65
Ton-miles per mile, million	1.9	3.5	5.1
Wabash River:			
Tons, million	3.5	10.8	21.4
Ton-miles, billion	.32	.97	1.9
Ton-miles per mile, million	2.3	7.2	14.3
Total ton-miles (rounded), all new waterways, billion	1.2	4.5	6.1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

WATERBORNE FREIGHT TRANSPORT
GROSS DEMAND IN OHIO BASIN STUDY AREA

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 21

C. CAPABILITY OF GOING PROGRAMS

The going basin program for navigation includes the projects in the July 1965 program and also the Mound City and Smithland locks and dams, Ohio River, which by the end of 1965 had entered preconstruction status. Capabilities of the facilities in the going program to accommodate waterborne traffic are measured on an annual basis. This procedure is considered to obtain reasonably representative values as compared to distorted estimates that could result from use of a shorter time period. Navigation on Ohio Basin streams is essentially all on canalized reaches, and construction and replacement programs underway in 1965 contemplated continuation of the same conditions. Capabilities of canalized streams are limited by physical features of the waterways and by operating procedures of the waterway carriers which have been tailored to best meet the demand for water transport in the basin.

Engineering features of locks and dams and other structures in the Ohio Basin navigation system were determined by the most favorable utilization of resources of the streams in relation to the needs of the expected traffic. The width, alignment, and streamflow characteristics of the Ohio River and its more important navigable tributaries, as improved by minor works, permit safe and easy transit of tows with length and width in excess of lock dimensions and with draft less than 9 feet. Navigation of Ohio River pools is virtually unimpeded except during periods of adverse river conditions due to ice, floodflow, and fog. There are a few short reaches on Ohio River tributaries that delay navigation. The effects, however, of these reaches on total stream capabilities are negligible, and the traffic capacities of the channels have not been approached. Besides stops required at terminals, interruptions of runs regularly encountered by tows occur at locks only. For all Ohio Basin waterways, traffic capacities of channels exceed those of related locks, thus capabilities of the waterways are dependent on lock capacities.

Maximum utilization of navigation lock capacities requires a continuous demand for lockages by tows of a length, width, and depth that will fill the locks in all dimensions. Waterway traffic, however, is composed of tows of diverse sizes (both in draft and barge formation), speed, and direction of travel, and the occurrence of demand for lockages is quite irregular. These conditions result in nonuniform use of locks, and actual tonnages passing through locks each year are far less than annual physical lock capacities. The characteristics of waterborne traffic have evolved over a-long period of years and reflect demands of the various elements in the basin economy. Characteristics of traffic pattern as affecting lock usage are not expected to substantially change in the near future.

The following paragraphs give a concise review of the capabilities of the various Ohio Basin waterways with facilities in the going programs in place. Factors and circumstances which limit the capacities of the individual segments of the system are discussed more in section IV.

1. Ohio River

Existing modern locks and dams together with those which by the end of 1965 were under construction and in preconstruction planning, will result in a system of high-capacity dual locks, 110 by 1,200 and 110 by 600 feet in size, at each except four locking points. At its present stage of progress, the Ohio River lock and dam modernization program does not yet include the replacement of the Gallipolis dam-lock structure and the three uppermost ones below Pittsburgh. The capabilities of the locks at these four locations are considerably less than those of the modern replacement units. The old structures will restrict the continued growth of traffic in the Huntington, W. Va., reach of the river and in the Port of Pittsburgh. The capability of the Ohio River waterway summarized later reflects the capacities of the 15 modern structures in the going replacement program and the older 4 dam-lock units not yet encompassed by the program.

2. Major canalized tributaries of the Ohio River

The traffic capacities of navigable tributaries of the Ohio River are directly affected by the capabilities of works and navigating conditions on the Ohio River. Most of the traffic on the tributaries also uses the Ohio River as shown by tables 2 through 9. As indicated in figure 17, the share of the total individual tributary traffic which also moves on the Ohio River ranges from 46 percent for the Monongahela River to 98 percent for the Green River. The most favorable navigation conditions prevail when tows suitable for the Ohio River can efficiently ply the tributaries with minimum change in tow composition. Tow characteristics for this type traffic, such as barge sizes and loadings and tow formation together with towboat power and size, are designed with consideration of conditions on both the tributaries and the Ohio River. Characteristics adopted for the Monongahela and Cumberland Rivers navigation facilities contemplated by plans and programs in 1965, reflected towing practices expected on the Ohio River after the ultimate modernization of that waterway. Characteristics of navigation structures completed in 1956 on the lower Green River were selected under similar considerations.

The reconstruction program for the Monongahela waterway has not advanced sufficiently to include all obsolete structures. Completion of construction under the 1965 program without further replacements would result in modern locks of suitable capacities throughout the river with four exceptions. These are (a) two locks of small capacity in the upper middle portion of the river and (b) two moderate-size locks in the lower river with a capacity less than that of the locks just below and above. The capability of the waterway as listed later reflects both the inadequate capacities of the two locks in the upper middle river and the lesser limitations imposed by the other two.

Completion of the 1965 program on the Cumberland River will provide a 380-mile waterway, suitable for modern navigation and of adequate capacity, from the Ohio River to Celina, Tenn.

The capability of locks on the lower Green River is considerably in excess of current traffic, and the capacity of the waterway is expected to be sufficient to allow for the projected growth of traffic until the 1980's. Even before the failure in 1965 of dam No. 4, freight traffic on the upper Green River and the Barren River was small. The Green-Barren waterway upstream from the modernized lower, 106-mile reach has no capability at present, but the upstream locks have not been deactivated and restoring navigation to Bowling Green is being considered.

Navigation facilities on the remaining significant tributaries in the Ohio Basin study area - the Allegheny, Kanawha, and Kentucky Rivers - were constructed many years ago. The Allegheny River facilities are of small size, but the capabilities are expected to be adequate for traffic for several decades except perhaps in the lower river reach as Pittsburgh grows upstream. Obsolescence of the Kanawha River facilities will be hastened by the simultaneous occurrence of an increasing demand for water transport on the stream and larger tows expected on the modernized Ohio River. Kentucky River traffic has remained less than 500,000 tons annually for many years, and there are no indications of any significant increase with the present navigation facilities in place. Capability of the existing project is considered to be equivalent to the current traffic.

3. Capability of waterways system

The capabilities of the study area waterways based on locking studies and with consideration of expected variable traffic conditions at locks are summarized in the following tabulation. The listed capabilities are considered the maximum practical, denoting limits at which existing improvements should be replaced or major modifications made.

Waterway	Freight transport capability in billion ton-miles annually
Ohio River	34.0
Allegheny River	.09
Monongahela River	1.8
Kanawha River	.9
Kentucky River	.03
Green and Barren Rivers	2.0
Cumberland River	3.8

D. NET DEMANDS

The future need for further development of navigation resources in the basin is based (1) on the demands determined in subsection III(B) that are in excess of the capabilities of the existing waterways and (2) on the gross demand for water transport projected in that subsection for the potential new waterways. The following table summarizes these data:

TABLE 13. - OHIO BASIN WATERWAYS CAPABILITY AND DEMAND FOR WATER TRANSPORT IN BILLION TON-MILES ANNUALLY

Waterway	Capability of waterways with facilities in going programs in place	Actual traffic, 1965	Projected demands					
			Gross			Net in excess of programmed capabilities		
			1980	2000	2020	1980	2000	2020
Existing:								
Ohio	34.0	23.27	42.0	76.0	127.0	8.0	42.0	93.0
Allegheny	.09	.06	.07	.1	.13	-	.01	.04
Monongahela	1.8	1.79	1.9	2.2	2.5	.1	.4	.7
Kanawha	.9	.71	1.4	2.7	4.2	.5	1.8	3.3
Kentucky	.03	.02	.06	.12	.21	.03	.09	.18
Green-Barren	2.0	1.03	1.9	3.2	4.1	-	1.2	2.1
Cumberland	3.8	.45	.8	1.7	3.2	.02*	.1*	.2*
Total	42.62	27.33	48.13	86.02	141.34	8.65	45.60	99.52
Potential:								
Lake Erie-Ohio River[1]	-	-	0.6	3.1	3.5	0.6	3.1	3.5
Big Sandy-Levisa Fork	-	-	.25	.45	.65	.25	.45	.65
Wabash	-	-	.32	.97	1.9	.32	.97	1.9
Total	-	-	1.17	4.52	6.05	1.17	4.52	6.05
Grand total	42.62	27.33	49.30	90.54	147.39	9.82	50.12	105.57

* Upper river extension only.

[1] Data are for 61-mile Ohio Basin section only.

SECTION IV. PROBLEMS AND POTENTIAL SOLUTIONS

The study area has been critically examined to determine water transport needs, navigation problems, and reasonably practicable waterway improvement possibilities. Basic considerations were the expected future distribution and magnitude of waterborne freight traffic needs, the capability of present waterways to meet those needs, and the physical and economic practicality of providing the needed increases in capability both for waterways of the existing system and by the addition of new elements.

A. GENERAL

The development of navigation in the Ohio Basin has had certain effects, mostly advantageous, on other problems and needs connected with the streams or the use of water and related land. Conversely, developments for solving surface water problems have generally benefited navigation.

ACTIVITIES AND FACTORS INTERRELATED WITH NAVIGATION

Water transport and related improvements have had an impact on, and in turn, have been affected to varied degrees by activities and factors discussed in succeeding paragraphs.

1. Floods and flood control

Navigation improvements in the Ohio River Basin have no important direct effects on flood control. Because of the high level of physical development along the Ohio River and many of its tributaries, it generally has not been feasible to provide flood control storage capacity in the projects for navigation. Barkley Dam on the Cumberland River is an exception, with flood control and other purposes included besides navigation in the project. A favorable combination of advantageous topography and the small number of large-scale physical improvements which existed in the reservoir area before inundation provided opportunity for inclusion - in conjunction with the navigation pool - of flood storage capacity in the project. This has resulted in a substantial reduction in the floodstages on the lower Ohio and Mississippi Rivers. Barkley Canal, built mainly to afford navigation alternative routes between the Ohio River and the Cumberland and Tennessee Rivers also permits interchangeable storage of floodflows in Barkley and Kentucky Reservoirs. Tygart Reservoir on Tygart River, W. Va., is one other project that was built mainly for navigation purposes but also effectively serves flood control.

Care has always been taken to plan and design navigation improvements so that they would not increase river stages during floods. At the high-dam projects on the Cumberland where flood control is not an integrated purpose, prudence nevertheless has been exercised by allowing for space above normal pool, to replace the natural valley storage lost by building the structure.

Traffic passing over navigable dams, or navigable passes in dams, is not affected by floodstages. Navigation structures with a nonnavigable dam, however, may block navigation for certain periods when high flows cause an outage of the lock. Suspension of traffic for other than a short time may result in serious economic loss. The impact of floods on river commerce is a consideration in the study area's waterways modernization programs. The composition of the new navigation structures' elements is such that the effect of floods is reduced to within acceptable limits; namely, duration of lock outage is on the average less than one day per year. Various programs are continuing to lower the flood profiles in the basin's waterways. As a result, interruption of navigation due to high flows is progressively becoming insignificant.

The storage and regulation of floodflows by reservoirs is very beneficial to navigation. Impoundments such as Lake Barkley may be an integral part of a navigable waterway or, like the Allegheny Reservoir, may not be in the immediate vicinity. In any case, without these reservoirs, a single-purpose navigation system would be subject to a much wider range of natural fluctuations of river stages. An adequate series of flood control reservoirs, either on the navigable streams or on their tributaries, improves the flow regulation necessary for an efficient waterway system.

The chief advantages to navigation from reservoir storage control of high and low flows are as follows:

a. The frequency of high stages and the magnitudes of floods are reduced. Thus a more stable navigation route is created, which is open to traffic nearly year-round by greatly reducing lock outages and terminal shutdowns due to floodstages. Accordingly, service on the waterways becomes more reliable - delivery schedules are met - and water transport's role in the economy is thus enhanced. Construction, operation, and maintenance costs of river terminals are also lower since provisions do not have to be made against as frequent or as wide fluctuations in water stages.

b. Streamflow velocities vary over a narrower range, and their average is reduced. Upbound tows are capable of greater speeds, and low-powered towboats can maintain schedules at smaller operating costs. Maneuverability of tows is also increased.

c. Maintenance, during seasonal droughts, of a steady, higher than natural flow increases low water depths in the navigation system, and thereby increases the draft potentials of tows and reduces the amount of dredging that otherwise would be required to maintain navigation depths. Besides, flow regulation in a waterway can diminish the formation of ice and expedite removal which, in turn, improves river traffic and reduces damage to navigation aids.

2. <u>Water quality control</u>

The navigation dams in the streams do not provide for low-flow storage in the pools they create, nor do they reduce the flow rates during low-flow

periods. The average low-flow velocities are decreased by the dams due to the increase in channel cross section. The effect of this on water quality is not yet completely known. Concern over a change in assimilative capacity of the streams within the navigation pools has been expressed, and the Corps of Engineers and the Federal Water Pollution Control Administration are currently cooperating in studies regarding this matter. The Federal Water Pollution Control Administration has estimated the minimum streamflows required to assimilate projected waste loads in the basin's navigation pools. (See "Appendix D: Water Supply and Water Pollution Control.") Storage for maintaining these flows is provided in the basin framework plan.

Tygart Reservoir, W. Va., is a project which, while operated in the interest of navigation, may also increasingly benefit water quality control in conjunction with appropriate waste control measures in the drainage area above and below the dam. Similarly, Grand River Reservoir, conceived to supply navigation water for the potential Lake Erie-Ohio River Canal, would augment the low flows in the Mahoning and Beaver Rivers enough to mitigate adverse effects of their canalization. These flows, entering the Ohio River in turn, would improve the water quality therein.

River dredging (and disposal of dredged material) associated with construction or maintenance of navigation projects may create problems for industries and municipalities by causing changes in the quality of their streamwater supply. Such problems usually could occur if the suspended-solids load of a river is significantly increased by dredging operations. Adverse effects may under certain circumstances have also toxic, bacterial, biological, chemical, or other aspects. Project conditions for dredging operations vary widely, and to delineate pollution abatement measures which may be necessary requires detailed analysis of the factors involved.

Waterway operators, through their pollution abatement and education committees, have been quite active in planning and applying procedures and equipment necessary to reduce their contribution of pollutants entering navigable waters. An example of effort in this regard is the recent launching in the Ohio River of a 5,200-hp. towboat with a sewage treatment and incinerator system incorporated in the design. Another example is the phasing out by the bargelines of single-skin petroleum barges and their replacement with double-skinned units. This shift to modern tankers has greatly contributed towards diminishing water pollution by oil leakage. Under the Clean Water Restoration Act of 1966, the inland waterways transportation industry may receive Federal grants for the development or demonstration of new or improved methods of preventing industrial pollution of waters.

3. Recreation

One of the most widely appreciated public benefits of navigable rivers, canals, and lakes in the Ohio River Basin is their use for recreation. In the boating season, millions of recreational-craft users crowd the

waterways with a wide variety of floating equipment from simple skiffs to luxury yachts. The Federal Government, the States, and local political entities, as well as private companies and individuals, have built launching, docking, and service facilities for recreationists throughout the waterways system. Canalization of navigable streams by the construction of dams and locks creates slack water pools which are ideal for pleasure boating. The July 1965 program encompassed more than 370,000 acres of navigation pool area available for general recreational use, of which 230,000 acres are on the Ohio River. In addition, grounds in the vicinity of many locks are used extensively by picnickers. A great number of people come to the locks simply to enjoy the view of the river and the water traffic. In 1965, visitation at the Ohio River locks aggregated more than 1.1 million.

Several of the navigable tributary reaches have declined in importance as commercial arteries but are now among the finest recreational areas in the basin. Recreational boating has become one of the principal uses of the Kentucky River as its lock-and-dam system has continued to lose usefulness for modern freight traffic. In 1954 the Government ceased operating the Muskingum River navigation system because no freight was moving on it. The system has since been rehabilitated by the State of Ohio for small-craft use. The waterway's assets for public recreation have been generally recognized, and the creation of a national recreational area along the river recently has received some consideration. On the other hand, the waterways which are busy with cargo-carrying traffic, are not without hazards for the small-boat navigator. Since both cargo-carrying and recreational traffic will continue to grow in the future, operating adjustments, equitable to both interests, will be necessary for safe use of the navigable waters.

4. <u>Fish and wildlife</u>

Navigation improvements may have beneficial and detrimental effects on fish and wildlife. Appendix H, prepared by U.S. Bureaus of Sport Fisheries and Wildlife and Commercial Fisheries, refers to long-range, historical effects brought about by the physical alteration of the navigable streams by dam construction, channel deepening, turbidity, and replacement of the free-flowing rivers with slack water navigation pools. Beneficial effects from navigation dams include the creation of embayments and back channels. The expanded shoreline provides sportsmen with a greater number of angler sites and better opportunities for a safe access to the rivers. Besides, tailwater fishing below the dams is considered one of the most rewarding experiences. Thousands of acres of land acquired by the Government for navigation projects have been withdrawn from other uses and thus have become available for game preservation and enhancement. Many such areas have been turned over to State agencies for implementing, operating, and managing wildlife programs. In the fall, when many waterways become flyways for migrating birds, a further recreational opportunity becomes available to the outdoorsmen. In that season, the navigable rivers and canals provide waterfowl hunting for many sportsmen. Navigation project

lands provide thousands of acres of wildlife habitat which are open to the public for hunting and fishing.

Benefits and detriments to fish and wildlife resources are evaluated for all navigation improvements considered for authorization. In cases where damages to these resources are expected to occur, mitigation measures are provided. Similarly, if found feasible, measures for fish and wildlife enhancement are included as a primary project purpose.

5. Hydroelectric power

Development of hydroelectric power at most of the navigation structures has been impracticable because of the substantial fluctuations in stage and flows and the low powerheads available. Today, however, integration of power generated at river projects having significant head, into readily available grid systems, provides an opportunity for economical low-head waterpower production. The following tabulation gives the installed capacity, average annual generation, and annual returns to the Federal Government for existing hydropower installations built in conjunction with navigation projects in the basin:

Stream and navigation dam	Existing installations: Installed capacity (mw.)	Existing installations: Average annual generation (1,000 mw.-hr.)	Average annual return to U.S. Government: Rental fee	Average annual return to U.S. Government: Power sales
Ohio River: McAlpine	80.3	369	$95,000	-
Kanawha River:				
Winfield	14.8	100	40,000	-
Marmet	14.4	80)	64,000	-
London	14.4	80)		
Kentucky River: No. 7	2	11	4,700	-
Cumberland River:				
Barkley	130	582	-	$2,200,000
Cheatham	36	160)	-	2,400,000
Old Hickory	100	420)		
Total, all basin navigation projects	391.9	1,802	203,700	4,600,000

Barkley Canal, connecting the lower Cumberland and Tennessee Rivers, was conceived to provide navigation on these streams with alternative routes to and from the Ohio River and to create a-shortened route for traffic between the Cumberland and Mississippi Rivers. However, over and above the value to navigation, hydropower generation gains 102,200 mw.-hr. annually by a purposeful routing, via the canal, of the flows in the connected rivers to the power plants in Barkley and Kentucky Dams.

Only a small part of the hydropower potential at navigation projects in the Ohio River Basin has been harnessed. The undeveloped potential on the waterways in the study area has been estimated at a total installed capacity of 1,145 mw. with an annual average generation of 5,397,000 mw.-hr. A detailed discussion of the power potential at navigation structures is contained in "Appendix I: Electric Power Resources and Requirements in the Ohio River Basin."

6. Utilities

The navigation pools in the basin have benefited many municipalities and industries, including thermal power plants, by providing them with a stable, dependable source of water supply. Without these pools, many low dams would be required at water intakes in the rivers in order to have desirable pondage during low water periods. The navigation pools in the July 1965 program are in or adjoin 116 (30 percent) of the counties in the study area. Three-fourths of this number make use of the opportunity and withdraw pool water for municipal and industrial purposes. The following tabulation portrays the importance of the navigation pools to water supply in the region.

	Number of water supply beneficiaries of navigation pools				
	Drawing water directly		With indirect pool water supply	Contiguous counties	
	Munici-palities	Indus-tries	Off-stream communities	Total	Using pool water
Pools of -					
Ohio main stem	51	120	68	74	49
Allegheny River	16	37	55	4	2
Monongahela River	22	52	71	7	7
Kanawha River	15	27	30	4	3
Kentucky River	11	19	5	15	11
Green and Barren Rivers	5	4	2	8	6
Cumberland River	23	3	10	16	10
Total in study area	143	262	241	[1] 116	[1] 86

[1] Counties contiguous to more than one waterway are counted once.

It should be noted that the tabulation does not include numerous industries which receive pool water through municipal distribution systems. Furthermore, since navigation pools generally increase the level of ground water stored in the aquifers along the river during low flow periods, they contribute to the regular replenishing of the supply drawn from inland wells. With significantly increased ground water yields, the potential for industrial development is even further enhanced. Higher navigation pools may require alterations to the outfalls of storm and sanitary sewer

systems constructed with reference to existing river stages. In addition, higher pool levels may be the origin of increased infiltration in sections of existing sewer systems after new ground water levels are established.

7. Agriculture and land use

Inland navigation contributes materially to agriculture's well-being by providing low-cost transportation - an important cost element in modern farming - for fertilizer materials and products, fuel for farm machinery, and farm products. Farm products are transported over continental distances to major population centers and to seaports for export, and achieving a low delivery cost is of great significance to the consumer at home and abroad.

An increase in ground water volumes attributable to navigation pools may enhance agriculture by supplying additional beneficial soil moisture. On the other hand, a ground water table raised by higher navigation pools may alter the established drainage pattern and require modification of existing agricultural drainage systems.

The availability of an improved waterway may tend to attract industry and commerce along its banks and to spur urbanization, thus contributing to a changed use of adjacent lands. In planning a new waterway, the nature and extent of its effect on agricultural and community values should be carefully appraised in the light of local, regional, and national objectives.

8. Bridges

The construction costs of bridges as well as their approaches are often significantly increased by required clearances over navigable waterways. Installation of navigation improvements often requires modification of bridges crossing the project in order to provide acceptable clearances and/or channel depth. During the early stages of river development, little consideration was given to the effect of bridges on navigation. Several bridges built nearly 100 years ago still cross navigable waters in the basin. They restrict tow sizes and contribute to the hazard of poor visibility. In bad weather, tows have been delayed in transit by not being able to clear such bridges, modern electronic devices notwithstanding. In recent years, the practice has been to strike a balance between bridge costs and navigation costs including those arising from restrictions on towboats and commodity transport.

Study efforts to establish minimum vertical bridge clearances which would best serve both the public's economic and national defense interests led to the adoption, July 14, 1966, of standards applicable to the entire Ohio River. New bridges over the stream will have navigation spans which clear the river by both a minimum of 55 feet above the stage which is equaled or exceeded 2 percent of the time and a minimum of 69 feet above the stage coincident with average June flow. As the physiographic features

of individual waterway reaches differ greatly, no one standard for horizontal bridge clearance can be applied throughout the basin. Such clearances are determined for each bridge by detailed studies of the conditions.

9. Bank protection

The enormous energy of the rivers in flood tends to erode soft strata along the banks and in the flood plain, and the material is carried downriver where it is deposited later as the streams slow down to normal flow. The phenomenon affects all navigable reaches in the system insofar as it adds to the volumes of material that have to be continually cleared, snagged, and dredged from the channels in order to maintain navigable channel depths. There are no unusual aspects to this program for the Ohio River system, and bank erosion does not pose a serious problem to navigation in the study area.

Wind waves generated on navigation pools also cause bank erosion necessitating protection of lands and highway and railway embankments in some areas. The wave action from high-speed recreational vessels and commercial tows contributes to bank erosion but is not now nor expected to be a significant problem. Since most of the erosion takes place within the normal high-flow streambed, the problems are primarily local.

10. Physical waterway environment

The overall physical waterway environment including channel dimensions, required lockings, and compatibility of the various system sections, distinctly influences the productivity and growth of towing operations. The effects of channel width and depth on tow navigation has been well analyzed technically in model and prototype tests. As an extension of this effort, quantitative research was made on the effect of channel dimensions on the economics of bargeline operations. Ample waterway width and depth tend to increase the efficiency of tow performance. The observations were made that (a) for increased width of channel, the effect on output ceases to be significant for widths approaching twice the tow breadth and (b) the effects of increased depth is notable over a wide range but most pronounced for depth-draft ratios up to 4.0. In addition to the hydraulic efficiency of a generously-sized waterway, another type of efficiency is more important. Bulk-commodity carriers normally take advantage of added channel depth to increase the loaded draft of their vessels. The heaviest possible payloads per trip related to an acceptable speed and power input produce an efficiency of paramount importance in cargo movement. Heavy traffic needs channels sufficiently wide to permit the safe passage of two-way traffic without undue reduction in speed. The replacement program providing deeper and wider pools in the Ohio Basin, though but partly completed, has already had a remarkably beneficial effect on towing operations.

With the development of high powered towboats and large bargetows, operational speeds have become important to inland navigation, particularly as pertains to locking delays and other losses of time. The larger the

boats and tows become, the higher the hourly operating cost and, therefore, the greater the need for eliminating or reducing delays. Besides the tow delay operating cost, these delays affect the reliability of service. Regular deliveries on a firm schedule may be more highly valued than the speed of deliveries.

Lock sizes are of utmost importance for the expansion of waterway traffic. Some locks built in the past have outlived their usefulness before the end of the structures' life span. Locks that are large enough to permit single lockages of the tows which will serve a mounting traffic in the future probably will be most efficient. The number of lockage points along a waterway is also a factor in the growth of waterborne freight traffic. The fewer lockings along the route of a tow, the faster it will transit, accomplishing the haul at lesser cost. The modernization program on the Ohio River, although not yet completed, has already shown a remarkable effect on the speed and reduction of delays in bargeline operations. The fewer navigation structures along the path of tows also reduce the chance of unpredictable delays caused by occasional traffic tieups at these structures.

11. Navigation system extensions

Extensions to a system of navigable waterways usually add to the growth of commerce in the entire system. The broad factors of geography and topography, however, are major influences on the economical expansion of a navigation system. Lack of suitable natural water courses limits the extension of inland waterways. An artificial canal may become a trade route, but this may be an expensive means of transport, and alternatives may be more feasible. Construction of any of the potential waterway extensions for which there would be a future need will undoubtedly result in added traffic growth in the basin.

12. Climate

Ice forming on the waterways or floating in from tributaries and upstream reaches may impede or stop traffic for certain periods. During the period 1929-66, the Ohio River was closed to navigation due to ice conditions 14 times at Pittsburgh, Pa., 12 times at Parkersburg, W. Va., 10 times at Cincinnati, Ohio, and 6 times at Paducah, Ky. The average closure varied from about 1.3 to 4.3 days. However, the system of higher lift replacement structures is expected to reduce the obstruction to navigation caused by ice.

Fog on the waterways causes traffic to slow down or stop. This condition occurs on the average about 5 percent of the time on all basin waterways and is not limited to any particular season. Recent advances in radar equipment used by practically all bargetows have resulted in a better selectivity of images thus increasing the safety of navigating in fog. Continual improvements in equipment will further reduce the effect of fog on water transport.

Insufficient low-water supply is a limiting factor in the expansion of inland navigation. In a canalized system, the need for lockage water increases with growing traffic which requires a greater number of lockages. Water releases from reservoirs built for purposes other than navigation usually have an incidental beneficial effect on navigation water supply. Today the latter is adequate throughout the basin. Table 14 compares the needs for lockage water under conditions of maximum practicable demand for lockings at the most critical locks with the available and prospective water supply. Climate and hydrology in the study area, coupled with water-related development programs for the various resource uses, are expected to provide streamflows which will satisfy all demands arising from waterborne traffic in the existing and potential waterroutes.

13. Traffic congestion

The replacement of all old, navigable-dam structures on the Ohio River has been authorized since December 1965, but two of the key units in the modern system are still in the planning-for-construction stage, and several others are in initial construction phases. Movements in the early 1970's will continue to be more costly because of congestion in the residues of the old system. For the next decade, the presently inadequate lower Ohio River reach will be depriving inbound and outbound Tennessee and Cumberland River traffic of the full benefit potential of the modern navigation systems in these streams. Another recent development connected in a general way to waterway congestion is the increase in recreational boating on the cargo-carrying waterroutes in the basin. This use of the waterways is to a degree in conflict with freight-moving navigation. The bargeline industry, to reduce operating costs, has invested substantially in equipment capable of high speeds. However, in certain reaches they are prevented by speed limits and other regulations from fully using their equipment. Recent Federal legislation on "rules of the road" is aimed at conditions where small craft hamper the safe passage of commercial tows. Enforcement of the law's provisions may eventually aid in minimizing the problem. The broad principle of zoning the waterways for different uses has also been introduced in discussions on deriving optimal benefits for the various user groups. One among several applications of this principle could lead to traffic lanes for the use of designated types of vessels. Considering that the demand by 2020 for water-based recreation is expected to be more than six times that in 1960, one can only conclude that, as a minimum, some form of traffic discipline will have to be applied in order to approach the equitable satisfaction of competing needs on the inland waterroutes.

14. Towing and terminal equipment trends

An important overall effect of water transport is to hold down the delivered cost of commodities - both those carried in waterborne commerce and those moved by other modes. In the highly competitive world of transportation, the bargeline industry must develop ways to reduce costs and increase efficiency. One phase of reducing costs is development of efficient floating and related shore equipment.

a. Historically, a breakthrough in power efficiency of vessels was most important for inland navigation's gaining a significant role in the Nation's transport activities. This came about first with the invention of the steamboat and then with the development of the diesel-powered towboat and tug. The development of the tunnel stern and the Kort nozzle increased thrust about 25 percent without increase in engine horsepower. Figure 22 shows a towboat now commonly being built for the inland waterways and the general range of its sizes. Given also is a view of the tunnel stern, propellers, Kort nozzles, and rudders of a modern townboat. The diesel engine appears to be for at least the near future the most economical power source.

Tank testing of hull forms, steering systems, and propeller size and pitch result in power vessels especially designed for maximum efficiency in the particular service for which they are built.

Towboats operating in 1964 in the Ohio River Basin ranged in capacity generally between 400 and 4,000 horsepower. It seems certain that the current standard of 3,000 to 4,000 horsepower for towboats pushing Ohio River tows will increase to a "standard" of 6,000 to 7,500. However, it is not expected that these substantially more powerful vessels will increase tow speeds more than 25 percent.

b. Recent changes in design of barges have resulted in (1) more efficient hull forms and fleet arrangements, (2) a wide variety of barges, some of which are highly specialized for particular cargoes, and (3) larger sizes. Figures 23 and 24 show the various barge types and their range of size now in use throughout the inland navigation system.

Following completion of the going programs for modernization and replacement of navigation structures in the Ohio River Basin, it can be expected that barges will have a standard depth from 12 to 14 feet instead of the current 11. The greater depths would make it possible to normally use a full 9 to 10 feet of draft, and much more during high water periods. Over the next 50 years, the number of barges in service is expected to increase more than threefold, whereas their total cargo capacity would increase about four times.

c. Material increase in operating efficiency is achieved with the reduction of idle time in the loading, unloading, and release of barges. To this end, river terminals have been especially equipped with machinery and warehouse facilities to accommodate the bulk cargoes of the tows. Operations have been so improved now that, in some instances, towboats can afford to wait while their complete tows (20,000 to 30,000 tons) are being loaded or unloaded.

15. <u>National defense</u>

The importance of inland waterways transportation for the Nation's defense was spectacularly demonstrated in World War II. Then, water

transportation on the Ohio River system, together with the other inland and intracoastal waterways, achieved two vital purposes: the moving of large quantities of strategic materials and facilitating widespread dispersal of essential war production throughout the interior, which eased the congestion in industrial coastal areas. Another remarkable wartime achievement attributable to the inland waterways was in the field of shipbuilding and repair. Many different types of ocean-going vessels and, in addition, many thousands of tons of structural ship sections were built in shipyards on the waterways in the Ohio Basin.

Because of their draft, many of these sea-going vessels had to be pontooned or otherwise floated and towed to deep water. To assist in this purpose, stream rises were occasionally induced by coordinated operation of navigation facilities in the Ohio River system. This demonstrated another facet of the flexibility of inland navigation.

Since the war, all phases and sectors of inland navigation have improved equipment, facilities, and operating techniques, adding measurably to the defense capabilities. Construction for the National Aeronautics and Space Administration's program, which contributes indirectly but significantly to the national defense, is eased by the availability of inland waterways at the Administration's various facilities. Often, moving of outsized rocket and equipment components between NASA's installations is feasible only by water.

TABLE 14. - CRITICAL LOCKS FOR NAVIGATION WATER REQUIREMENTS IN THE OHIO BASIN STUDY AREA

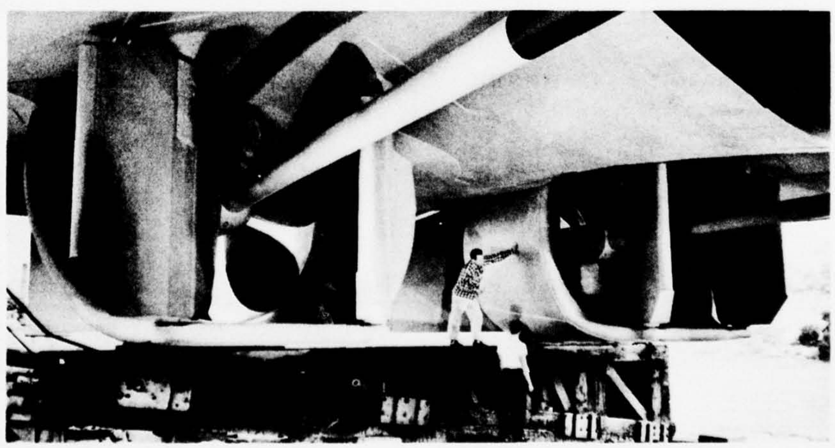
Stream	Lock				Water use per lock filling (ac.-ft.)	Maximum practicable number of lockages per day	Percent of daily lockages requiring lock filling	Lockage water need (ac.-ft. per day)	Total amount of water needed, leakage included (ac.-ft./day)	Minimum low flow supply available		Additional amount required		Remarks
	Designation	Location (river mile)	Size (ft. x ft.)	Lift (ft.)						(c.f.s.)	(ac.-ft. per day)	(c.f.s.)	(ac.-ft. per day)	
Allegheny River	No. 9	62.2	56 x 360	22	11.6	47	75	407	516	1,000	1,984	None		Minimum low flow is with 1965-program reservoirs operating.
			M 56 x 360 A 56 x 360(c)	22	11.6	60	75	522	631	1,000	1,984	None		
Monongahela River: Above L & D No. 8	Opekiska	115.4	84 x 600	22(b)	27.7	40	75	831	950	340	673	140	277	340 c.f.s. supply assured by Tygart River Reservoir and natural flows. Deficiency will be made up by releases from authorized Stonewall Jackson Reservoir and, below lock No. 8, from authorized Rowlesburg Reservoir.
Below L & D No. 8	No. 4	41.5	M 110 x 720(c) A 84 x 720(c)	16.6(b)	33.1 24.8	34 15.8	75 75	1,158	1,337	475 (7-day-10-yr.)	942	199	395	
Kanawha River	Winfield	31.1	M 56 x 360 A 56 x 360	28	14.7	60	75	664	849	690	1,366	None		
Kentucky River	No. 14	249.0	52 x 148	17	4.0	40	75	120	160	30	59	51	101	Minimum flow of 30 c.f.s. assured by Buckhorn Reservoir. Present water supply is considered adequate for now and the future.
Green and Barren Rivers	No. 2	63.1	84 x 600	14.3	18.0	40	75	540	639	306 (7-day-10-yr.)	6,063	None		
Cumberland River: Above Nashville	Old Hickory	216.2	84 x 400	60	52.0	34	85	1,508	1,657	5,745	11,375	None		Flow assured by Wolf Creek and Dale Hollow Reservoirs.
Below Nashville	Barkley	30.6	110 x 800	57(b)	125.7	34	85	3,645	3,923	7,885	15,612	None		Flow assured by Wolf Creek, Dale Hollow, Center Hill, and J. Percy Priest Reservoirs.
Ohio River	Emsworth	6.9(c)	M 110 x 1,200(c) A 110 x 600(c)	23(c)	73.6 38.8	34 8.3	75 75	1,877 241						
	Total				112.4			2,117	2,513	4,200 (7-day-50-yr.)	8,316	None		Minimum low flow is with 1965-program reservoirs operating.
	McAlpine	606.8	M 110 x 1,200 I 110 x 600 A 56 x 360	37	118.4 62.5 19.5	34 8.3 15	85 85 85	3,422 444 251						
	Total				200.4			4,117	4,592	10,000 (30-day-50-yr.)	19,800	None		Minimum low flow is with 1965-program reservoirs operating.

NOTE. - 1. Letters preceding lock sizes indicate the following: M - main lock; I - intermediate lock; A - auxiliary lock.
2. Letters after figures indicate the 1965 status of the pertinent feature as: (b) - being built; (c) - being considered.

MODERN RIVER TOWBOAT

RANGE OF PRINCIPAL SIZES AND POWER

LENGTH FEET	BREADTH FEET	DRAFT FEET	HORSEPOWER
117	30	7.6	1,000 to 2,000
142	34	8.0	2,000 to 4,000
160	40	8.6	4,000 to 6,000



VIEW OF THE STERN END OF A TWIN-SCREW TOWBOAT

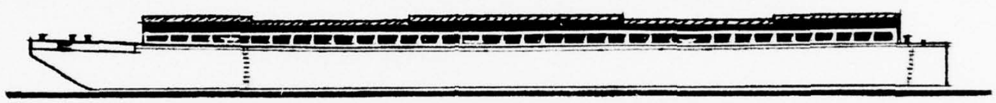
Courtesy of
THE AMERICAN WATERWAYS OPERATORS, INC.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

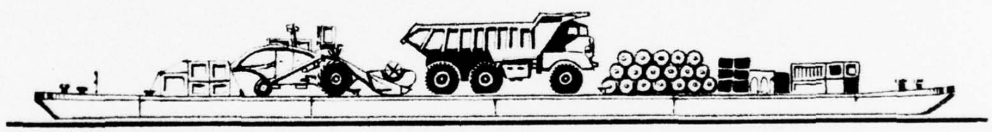
TOWBOATS
ON THE
INLAND RIVER NAVIGATION SYSTEM

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 22

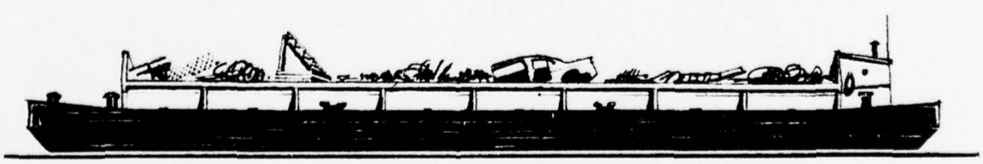
OPEN HOPPER BARGES	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
	175	26	9	1,000
	195	35	9	1,500
	290	50	9	3,000



COVERED DRY CARGO BARGES	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
	175	26	9	1,000
	195	35	9	1,500



DECK BARGES	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
	110	26	6	350
	130	30	7	900
	195	35	8	1,200



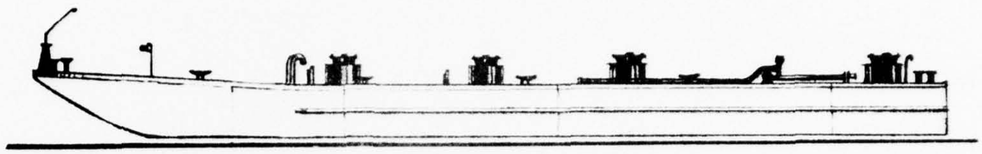
SCOWS	LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS
	90	30	9	350
	120	38	11	1,000
	130	40	12	1,350

Courtesy of
THE AMERICAN WATERWAYS OPERATORS, INC.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

DRY CARGO BARGES
ON THE
INLAND RIVER NAVIGATION SYSTEM

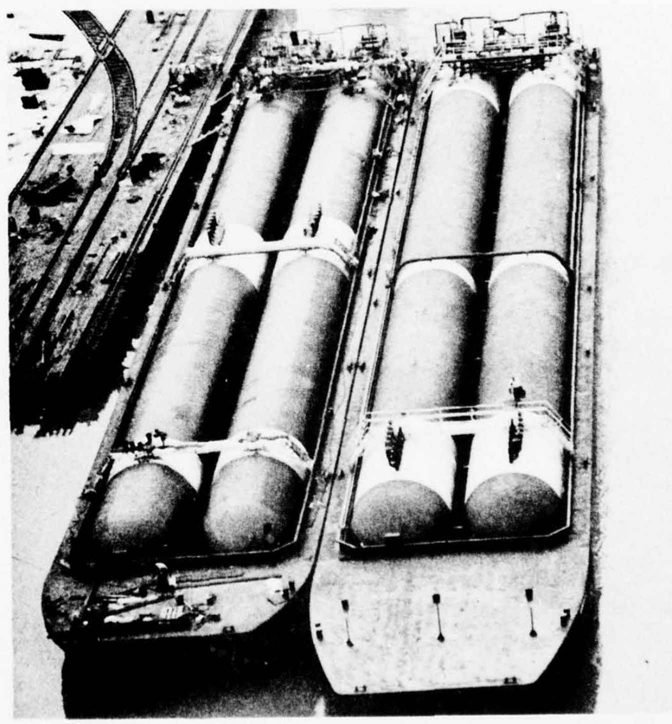
CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 23



RANGE OF PRINCIPAL SIZES AND CAPACITIES

LENGTH FEET	BREADTH FEET	DRAFT FEET	CAPACITY TONS	CAPACITY GALLONS*
175	26	9	1,000	302,000
195	35	9	1,500	454,000
290	50	9	3,000	907,200

*BASED ON AN AVERAGE OF 7.2 BARRELS PER TON AND 42 GALLONS PER BARREL



TYPICAL RIVER BARGES FOR TRANSPORT OF LIQUID CHEMICALS

NOTE THE GIANT INDEPENDENT CYLINDRICAL TANKS

Courtesy of
THE AMERICAN WATERWAYS OPERATORS, INC.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

LIQUID CARGO (TANK) BARGES
ON THE
INLAND RIVER NAVIGATION SYSTEM

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX L FIGURE 24

B. PROBLEMS AND DEVELOPMENT NEEDS

Navigation in the Ohio River Basin is expected to expand markedly as an integral part of the Nation's transport activities. The value of the basin's industrial output is projected to increase sevenfold over the next 50 years. This will be accompanied by a parallel development of transportation activities, with navigation sharing in this growth. A significant expansion in the study area's navigation facilities will be required to satisfy the future demand for water transport of bulk commodities used by the manufacturing and power-generating industries, for accessory construction work, and for many other needs of the growing population.

The following paragraphs describe notable future waterway improvement possibilities for a program to further develop freight-moving navigation in the Ohio Basin.

1. Ohio River

By 2020, the freight volume moved on the Ohio River is expected to be more than five times that of 1965 or, roughly, 530 million tons a year. Completion of the lock-and-dam replacement plan for the entire river is needed to provide for an efficient movement of future commodity tonnages. At some of the busy locks, navigation now is experiencing delays which result in a significant economic loss. Since congestions are becoming more serious in the lower Ohio River, accelerated completion of the modernization program in that reach is becoming most important. There are four old small-capacity locks remaining on the Ohio River which are not in the going replacement program. The most troublesome of these is near Gallipolis; it will be the only one having a 600-foot main lock in the middle reach of the river as the modern dam-lock units are completed. The other three, with a similar-size main lock, are located just downstream from Pittsburgh. The four are a serious impediment to meeting the projected demands of waterborne traffic, and eliminating them will become critical in the early 1970's. Replacing these old navigation structures is part of the modernization plan for the Ohio River navigation system but not yet implemented.

The Ohio River modernization plan when completed and maintaining the presently authorized 9-foot-minimum channel depth would provide a system with the practicable capacity of carrying the forecast volumes until about the year 2000. The efficiency and capability, however, of the waterway could be appreciably increased by constructing in the immediate future a navigation channel deeper than that in the existing project. The longer and deeper pools behind the new lock and dam units have provided significant reaches of the Ohio River with controlling depths of 12 feet or more. Preliminary estimates are that after completion of the replacement plan, 95 percent of the 981 miles of the Ohio River will have a minimum channel depth of 12 feet. Pertinent data regarding this depth for the 19 pools which are planned to ultimately comprise the canalized Ohio River, are presented in the following tabulation:

Twelve-foot channel depth in Ohio River navigation pools
with replacement program completed

Pool	Percent of time seasonal flows would provide channel depths of 12 feet or more throughout pool
Mound City	57.4
Smithland	100.0
Uniontown	100.0
Newburgh	60.5
Cannelton	70.0
McAlpine	56.5
Markland	68.4
Capt. Anthony Meldahl	100.0
Greenup	100.0
Gallipolis	100.0
Racine	100.0
Belleville	100.0
Willow Island	100.0
Hannibal	100.0
Pike Island	19.5
New Cumberland	99.9
Montgomery Island	100.0
Dashields	50.0
Emsworth	99.9

Towing operations in a continuous 12-foot channel would be more efficient, and bargeloads would be considerably greater. In anticipation of a greater depth throughout the Ohio River and to take advantage of cyclic high water conditions, some navigation interests have been using barges which can be loaded to a 10.5-foot draft. The extra 2 feet over the 8.5-foot draft limitation necessitated by the 9-foot channel increase the cargo capacity of a typical tow of 15 jumbo barges from 21,000 to 27,000 tons, or 28.6 percent. This is done with a very small loss in towing speed or with a low additional cost. Future barges are expected to have even greater drafts with more substantial operational advantages.

A further consideration for deepening the Ohio River channel is the need to provide for the projected tonnage densities on the stream. In 1965 traffic densities at Ohio River locks ranged between 16 and 29 percent of the yearly tonnage figure for the entire river. By 2020, a movement of nearly 155 million tons is expected through several of the structures, assuming the maximum ratio of lock to total river traffic would remain the same. The modern Ohio River units, with locks of 110 by 1,200 and 110 by 600 feet, have been designed for a practicable capacity of passing 122 million tons annually with a 9-foot-depth channel. This capacity estimate is based on a uniform flow of traffic. But this condition hardly occurs in actuality: the pattern of traffic at locks with regard to tow formation and draft, commodities moved, and spacing and direction of arrivals is

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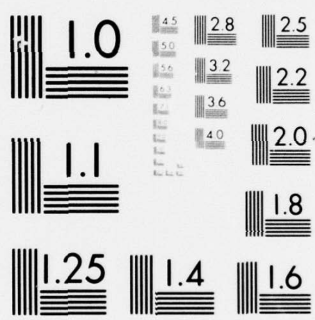


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

variable to a high degree. Due to this irregularity, tow operation through the new locks-and-dams system is expected to start losing efficiency by about 1980. The projected traffic density would create problems at the locks and in constricted downstream approach channels. To transport these tonnages over a 9-foot-deep channel, tows would have to be recycled more often than with a deeper channel. Thus, the greater number of tows moving to meet the demands of commerce will add to the congestion. With the continued increase in capability of marine power units and the restrictions imposed on tow sizes by the installed lock sizes and the natural curvature of the stream, the next most logical development for increasing tow tonnage and curbing traffic congestions would be to provide for deeper drafts. Some reduction in the expected congestion and delays at the modern navigation units could also be obtained by using haulage devices for speedy double-locking of future tows. Such devices should be developed and installed at locks when needed.

A 12-foot project minimum depth has been authorized for the entire 725-mile reach of the Mississippi River below the mouth of the Ohio River to Baton Rouge, La. The channel is progressively being contracted and stabilized to obtain the authorized depth, and the reaches where 12-foot channel depth has been provided are being gradually extended upstream towards the Ohio River. Seasonal flows provide a 12-foot depth below the mouth of the Ohio about 6 months each year.

The current channel conditions on the lower Mississippi River, the significant and continuous exchange of traffic between it and the Ohio River, the recent actions by a number of companies to increase at times loaded drafts to 12 and more feet, and the very substantial local traffic on the Ohio, all point toward a program for dredging a deeper channel throughout the entire 981-mile length of the Ohio River. A detailed study is needed to establish the optimal depth for a deeper Ohio River channel.

2. Allegheny River

Extending the future deeper Ohio River channel 30 miles up the Allegheny River will be needed before the year 2000. The deeper and also wider channel on the lower Allegheny would be required to serve the mounting traffic needs of the important manufacturing industry in the Pittsburgh region. The three small locks completed in the period 1927-34 in this reach have sills which are too high for a 12-foot-deep channel, and replacing the old structures in conjunction with providing the deeper channel would be advisable and practicable. Traffic trends for bulk commodities now indicate little need for future improvement of the navigation facilities farther upstream. Within 25 years, the five locks in the upper section of the slack water system will be obsolete from the standpoint of equipment and tow makeup expected to be used on the Ohio River. For recreational boating though, this reach is expected to grow in importance with the heavy demand for water-based recreation forecast over the next 50 years.

3. Monongahela River

More than half of the traffic on the Monongahela River does not leave the confines of the stream. Coal, by far the most important commodity, goes mainly downriver to supply the highly industrialized Pittsburgh area. The traffic is expected to expand with industry and the development of the mineral resources in the area. As coal reserves are depleted in the lower valley and new mines are opened in areas farther upstream, traffic particularly in the middle reach of the stream will intensify. The two locks which were built more than 40 years ago in the upper portion of that reach are approaching deterioration. Their single chambers, 56 by 360 feet, are very restrictive in capacity. Farther downstream, two other old locks with a main chamber, 56 by 720 feet, and an auxiliary, 56 by 360 feet, are of a lesser capacity than the modern structures located just downstream and upstream. The needs of future traffic will require the rebuilding of these old locks to provide for compatible navigation facilities throughout the waterway. Replacement or rebuilding of the four locks is included in the modernization plan for the Monongahela River system but not yet part of the ongoing program. The current plan for the waterway also includes a 2.1-mile extension, 200 feet wide and 9 feet deep, up the Tygart River, but building the channel has been deferred. Completion of the entire plan is required to meet the expected traffic demand in an efficient manner.

Concurrently with or shortly after a deepening of the Ohio River channel, a channel of comparable depth in the lower and middle Monongahela River to Morgantown Dam would be needed for economical operation in the reach. Because of the curvature of the stream, today's tow length of 700 feet is not expected to be exceeded, and future barges will need greater depths to efficiently move the projected ton-miles of river freight. Demands by 2020 on the coal reserves of the upper valley would require a similar deepening of the 29-mile reach above Morgantown Dam and also a widening to 300 feet of the 15-mile end section of the system channel.

4. Lake Erie-Ohio River Canal

A connecting waterway between the Ohio River and Lake Erie has been the subject of numerous studies and reports. Of the many routes considered, the Pittsburgh-Painsville-Fairport Harbor connection recently was found to be best. The project would be a direct navigation link between the systems of the Great Lakes-St. Lawrence Seaway, the Ohio River, and connecting waterways. Freight expected to move on the canal would be mainly iron ore (southbound), coal and coke (northbound), limestone, petroleum products, iron and steel, and miscellaneous chemicals. Barges commonly using the Ohio River system would move on the canal.

The Lake Erie-Ohio River Canal would meet a substantial demand for low-cost water transport in the area. Besides benefits to navigation, the proposed plan would provide additional flood control, low flow augmentation, potential for development of pumped-storage power, and considerable recreational resources.

5. Kanawha River

The needs of navigation place a high priority on the modernization of the existing Kanawha River project. Traffic delays occur on the waterway due to the inadequate size of the three, 56- by 360-foot twin locks in the system. The structures could hamper the continued expansion of the chemical industry in the valley and the development of the vast local coal reserves. The Kanawha River area manufacturing output is projected to grow 110 percent from 1960 to 1980, and the correspondent mining output growth would be 76 percent. This development will be accompanied by a nearly 2.5-fold increase in river traffic, making early modernization of the entire navigable reach essential. Since nearly four-fifths of the 1964 Kanawha traffic moved on other parts of the inland navigation system, the waterway should be developed to function as an integral part of the Ohio River. Construction of a new Kanawha River lock system should be scheduled for about the time a modern dam-lock unit is completed near Gallipolis on the Ohio River. To continue efficient water transport on the Kanawha, the waterway would have to be deepened concurrently with the provision of a greater depth in the Ohio River channel.

The feasibility of modifying the existing navigation facilities will be investigated in the current Kanawha Basin Comprehensive Study scheduled for completion in 1969. The Appalachian survey report, to be completed by the end of 1968, will include the aspect of navigation for developing the area resources.

6. Big Sandy River and tributaries

Operation of the Federal navigation project on the Big Sandy (26.8 river miles with three locks), Tug Fork (12.5 river miles, one lock), and Levisa Fork (17.5 river miles, one lock) was discontinued in 1947, except lock No. 1, near the Ohio River, which was operated until 1952. The system was abandoned for lack of traffic caused primarily by system obsolescence and the fact that it did not extend into the coal producing area. Dam No. 1 was removed in 1962 to permit navigation from the Greenup pool on the Ohio River. Shortly thereafter, waterway traffic in this reach increased sharply. It serves the expanding industries on the lower Big Sandy River.

Potential improvements in the Big Sandy basin include a 9-foot-deep waterway extending from the Ohio River to miles 65 and 100 on Tug and Levisa Forks, respectively, and 10 nonnavigable dams with single locks - 2 on the Big Sandy and 4 each on Tug and Levisa Forks. Bituminous coal is the primary commodity that would move on the waterway. A demand of considerable magnitude for freight transport over a Big Sandy River-Levisa Fork waterway has been established, but economic feasibility of canalizing the streams has not been proven. A modern navigation system on Big Sandy River and its tributaries would enhance the development of the region. This aspect will be covered under the current Appalachian study. The projected growing demand for low-cost transport of the area's coal resources indicates the project will be needed after the year 2000.

7. Green and Barren Rivers

Growth of waterborne commerce which followed the 1956 modernization of the lower Green River prompted investigations to determine the feasibility of providing modern navigation facilities on the upper Green and the Barren Rivers. Coal, grain, rock asphalt, crushed limestone, petroleum, and sand would be susceptible to barge transport on this waterway.

By 1980 the outputs of the manufacturing and the mining industries in the Green and Barren Rivers area are expected to have increased 132 and 82 percent over their respective 1960 values. Construction then of the considered multipurpose dam at Rochester, Ky., is expected to be needed to satisfy the water-related needs of the area. The project would eliminate the obsolete navigation system on the upper Green River and the Barren River. Inclusion in the dam of a navigation lock would be required to meet increased demands for transport of bulk commodities upstream of the present modern waterway section.

A navigable depth greater than the present 9 feet would be needed in the lower Green River for efficient barging operations at the time a deeper channel is provided in the Ohio River.

8. Wabash River

Development of a modern waterway for freight transport on the Wabash River is a potential improvement which would substantially meet the demand for waterborne commerce in the area. It is expected that with a growing demand for low-cost movement of agricultural products, fertilizers, petroleum, and coal, canalization of the lower Wabash to Terre Haute, Ind., will be needed in the period between 1980 and 2000.

The need for low-cost water transport extends north and northeast beyond the Wabash River basin divide. Coal, grain, sand and gravel, vehicles and machinery, iron ore, sulfur, petroleum, cement, and fertilizers are the principal commodities potential for waterborne traffic. A Wabash-Great Lakes waterway would be both a major through waterway and an important new outlet for commerce in the immediate tributary area.

9. Saline River, Illinois

Improving the Saline River for navigation has been investigated in several studies and reports. Potential waterway projects include a navigable channel to Harrisburg on the Middle Fork of the Saline River, 32 river miles above the Ohio River. A 1964 report on Saline River port facilities prepared by the Corps for the Area Redevelopment Administration considered coal and grain as the principal potential commodities for barge transport. The report concluded that improvement of a 7-mile navigation channel on the Saline and construction of harbor facilities at the head of the channel would be economically feasible after the provision of the higher slack water level planned for the Ohio River in the Smithland pool.

10. Cumberland River

The 9-foot-deep navigation project channel on Cumberland River is being extended under the 1965 program to Celina, Tenn., just below the site of the authorized Celina Dam. Construction of the latter has been deferred pending a restudy of its current justification and the feasibility of including a lock. The multipurpose project with navigation facilities is expected to be needed before 1980 and would extend the canalized river reach upstream from Celina to Wolf Creek Dam. That dam has no navigation lock. Upstream from it, on Lake Cumberland, depths greater than 9 feet are available for local traffic beyond Burnside, Ky., to near the mouth of Laurel River. In order to stimulate the economic development of the upper Cumberland River area, it has been proposed to bypass the barrier imposed on water transport by Wolf Creek Dam. Coal, timber, gasoline, and shale offer potentials for future river commerce on the upper Cumberland. Pneumatic systems, bucket and belt conveyors, pipelines, hydraulic and electric power lifts, and vertical and inclined barge lifts are potential alternatives to a lock for moving waterborne cargo past the dam. There would be no need for a lock or alternative transfer facilities at Wolf Creek Dam until through navigation at Celina is provided.

With future Ohio River channel depths greater than 9 feet, a comparable navigable depth on the lower Cumberland River would be needed for continuing efficient bargetow operations. A deeper waterway to Nashville would be first required, with an extension to Old Hickory Dam to follow later.

The existing lock in Old Hickory Dam, the one now being built as part of the Cordell Hull Dam project, and the lock considered in the current reevaluation of the Celina Dam project are all 84 by 400 feet. It has been proposed that these locks, which are located above Nashville, be made uniform in size with those below Nashville by doubling their length. However, based on the projected demand for waterborne freight traffic upstream from Old Hickory Dam, there would be no need for the larger locks in the foreseeable future.

11. Increased channel depths on major improved Ohio River tributaries

Programs for the modernization of navigation facilities have been underway on the Monongahela River since 1948 and on the Cumberland since 1950. These programs maintain the authorized 9-foot minimum depth. A similar program completed in 1956 on the lower Green River provided a 9-foot-deep navigation channel. Water transport carriers have demonstrated the need for deepening to 12 feet of certain 9-foot-deep reaches on major Ohio River tributaries, in particular the Allegheny, Monongahela, and Kanawha Rivers. Due to the large degree of interdependency between waterborne commerce on the various segments of the basin's navigation system, provision of greater depths on the tributaries probably should be concurrent with constructing a deeper channel in the Ohio River. Greater channel depth in the Ohio Basin waterways needs to be studied on a systems basis. A

detailed study would establish the optimal new project depths for the various system components and the best scheduling of construction.

12. Tributary channels in the backwaters of the Ohio River

Construction of the high-lift dams under the Ohio River replacement program extends slack water from the new navigation pools many miles up several of its tributaries which have no improvements for modern barge navigation. Navigable channels of greater depth and convenient docking areas have thus been created along many tributary streams. Tributaries which benefit from this development include the Saline, Great Miami, Licking, Little Miami, Scioto, Little Kanawha, and Muskingum Rivers. On some of these, private interests are considering building or have provided loading and unloading facilities for barged bulk commodities. Depending on favorable combinations of local circumstances, waterfront industrial development along some of the Ohio River backwaters is expected. Such industrial growth will be accompanied by increased demand for freight movement on the newly created feeder channels. To meet this demand, improvements in certain reaches of the natural riverbeds may be required.

C. COMPREHENSIVE DEVELOPMENT PROGRAM FOR NAVIGATION

The future development program for navigation encompasses additional improvements on waterways in the 1965 program and the development of new waterways. The potential program is given in figure 25 and in table 15. The existing waterways included in the future program are the Ohio River main stem and the Allegheny, Monongahela, Kanawha, Green, Barren, and Cumberland Rivers. The replacement program for the basin system - started in 1948 on the tributaries and in 1954 on the Ohio River - is estimated to cost approximately $1.64 billion, of which $1.32 billion would be for the latter. Through fiscal year 1965, there had been spent $489 million for this work, leaving $993 million to complete the replacement of Ohio River navigation structures and $156 million allocated to the navigation function of replacement projects to be completed on the tributary waterways. Future development program improvements to the existing system in addition to those in the current replacement plans are estimated to cost $312 million, with $123 million of this for providing a navigable depth of 12 feet minimum in the Ohio Basin system.

Potential new waterways included in the future Federal program are the Lake Erie-Ohio River Canal, the Big Sandy-Levisa Fork waterway, and the canalized Wabash River. They would add about 320 miles of navigation channels to those already in the study area and would carry about 6.1 billion ton-miles of freight by 2020. Although the Lake Erie-Ohio River Canal is needed before 1980, it is not expected to be developed until after that date. The other two new waterways will be needed within the period from 1980 to 2010. The cost of these projects has been estimated at about $1.13 billion including the Ohio Basin section only of the Lake Erie-Ohio River Canal.

The 1965 expenditures for basin navigation projects were about $80 million. To meet expected traffic demands, annual appropriations should be increased to a substantially greater annual average for the period 1965-80.

The following discussion defines the scope of the future comprehensive plan for navigation on existing and new waterways in the Ohio Basin study area.

1. Ohio River

The replacement of the remaining four old locks in the upper third of the stream should be included in the initial phase of the framework program for the waterway. This would complete the modernization plan by about 1980 at a total estimated expenditure after July 1, 1965 of about $993 million. The amount includes $753 million for projects in the 1965 program. A 12-foot or deeper navigation channel should be provided either concurrently with or immediately after the completion of the replacement structures. The cost of deepening would be on the order of $50 million.

The improvements in addition to those in the 1965 program would cost about $290 million and would provide a high-capacity 981-mile navigable channel generally 500 feet wide and 12 feet or more deep.

Navigation channels in the slack water which extends from the new pools on the Ohio River into several of the tributaries are considered part of the Ohio River project and should be improved when feasible.

2. Allegheny River

Deepening and widening the lower 30 miles of the waterway would cost about $10 million. Construction cost of modern locks and dams in that reach would be on the order of $70 million.

Completion of these improvements before the year 2000 would develop the lower Allegheny River to a waterway of adequate capacity. The 72-mile slack water channel would be 12 feet deep and 300 feet wide in the 30 miles downstream and 9 feet deep and 200 feet wide in the reach above.

3. Monongahela River

Replacement of the two restrictive single-chamber locks in the upper middle river, followed by the reconstruction of the lower two old locks and the extension of the 9-foot navigation channel up the Tygart River should be included in the initial phase of the framework program for the waterway. Completion of this work by about 1980 would accomplish the current modernization plan for the system at an estimated expenditure after July 1, 1965, of $143 million. This amount includes $19 million for completing projects under construction in 1965.

Deepening of the waterway from Pittsburgh to Morgantown Dam should be coordinated with the provision of a deeper Ohio River channel. The cost of the improvement in this 102-mile section would be about $20 million. Deepening of the 29-mile navigation channel above Morgantown Dam and also widening the upper section of that reach would follow later. The cost of this work would be on the order of $10 million.

Development of the Monongahela River system beyond that provided for in the 1965 program is estimated to cost approximately $154 million and would result in a capacious and efficient waterway, 131 miles long, 300 feet minimum wide, and with a project depth of 12 feet.

4. Lake Erie-Ohio River Canal

Because of the magnitude of the project and the feasibility of accomplishment, installation of the waterway would be after 1980.

First cost of the project allocated to navigation is estimated at $944 million, of which $690 million would be for the Ohio River Basin section. The waterway would be a 120-mile extension to the inland navigation

system. Project depth is 12 feet minimum, and the channel width, generally 300 feet. The canal section lying in the Ohio River Basin would be 61 miles long.

5. Kanawha River

Replacement before 1980 of the three small-capacity locks on the stream by larger ones compatible with the Ohio River system would cost approximately $90 million. The project for deepening the Kanawha River waterway should be concurrent with constructing a deeper navigation channel in the Ohio River. The cost of this improvement on the Kanawha would be on the order of $20 million.

Completion of this work would develop the Kanawha River to an important 91-mile segment, 300 feet minimum wide and 12 feet minimum deep, of the inland waterways system.

6. Big Sandy River-Levisa Fork waterway

Estimated first cost of the project would be on the order of $200 million. Completion of the work in the first years of the next century would add a 127-mile navigation channel, 12 feet minimum deep and 200 feet minimum wide, to the Ohio Basin waterways system.

7. Green and Barren Rivers

Initial cost of building a multipurpose dam with navigation facilities at Rochester, Ky., is estimated at $60 million, of which about $15 million would be allocated to navigation. A 12-foot minimum depth in the lower Green River could best be obtained by raising the two downstream pools at an estimated cost of $2 million.

These improvements provided after 1980 would result in a 212-mile waterways system of suitable capacity from the Ohio River to Brownsville on the Green River and Bowling Green on the Barren River. Minimum depths in the navigation channels would be 12 feet in the lower 109 miles of the Green River and 9 feet in the reaches above.

8. Lower Wabash River waterway

Initial construction cost of a canalized waterway along the Wabash between the Ohio River and Terre Haute, Ind., is estimated at about $240 million. Building the project between 1980 and 2000 would add 135 waterway miles, 12 feet minimum deep and 200 feet minimum wide, to the Ohio River Basin navigation system.

9. Cumberland River

Construction by about 1980 of the previously authorized Celina Dam project including a lock would extend the canalized Cumberland River

waterway 80 miles farther upstream to Wolf Creek Dam. Total first cost of the multipurpose project is estimated at about $69 million, of which approximately $10 million is allocated to navigation. With a modern waterway to Wolf Creek Dam assured, installation of a $4 million cargo lift (or a lock) at that dam would be practicable and advisable. This would extend the navigation system another 90 miles to near the Laurel River. A deeper navigation channel in the lower Cumberland River could be obtained by a combination of dredging and operating the pools at higher elevations. A 12-foot minimum depth provided after 1980 to Nashville would cost about $5 million. A later extension of the deeper channel to Old Hickory Dam is estimated at an additional $6 million.

Completion of the facilities on the Cumberland River that were in the 1965 program would require about $13 million allocated to navigation to be expended after July 1, 1965. Further $25 million would be required for projects needed later.

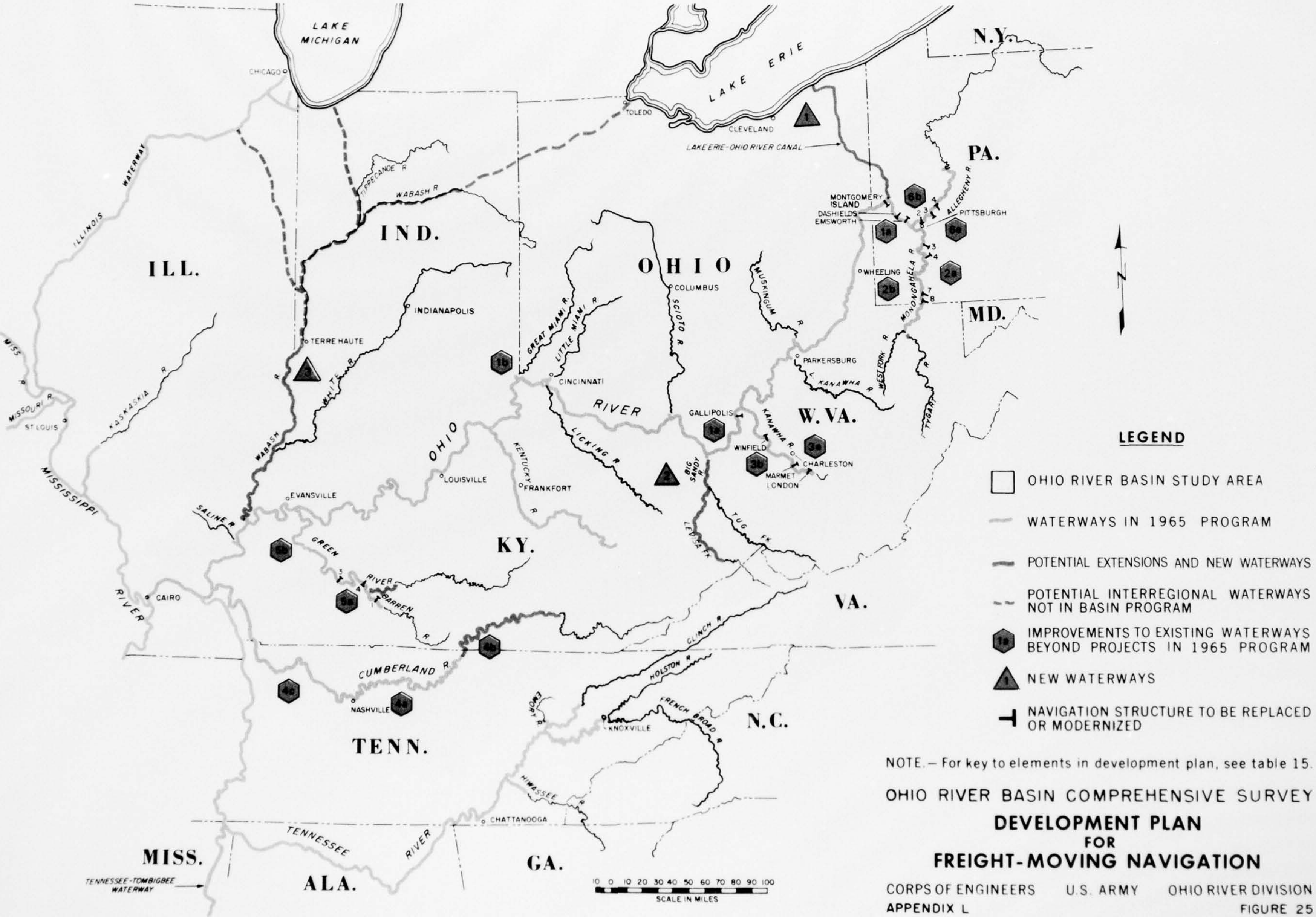
Implementation of the development plan for navigation on the stream would provide for an uninterrupted flow of commodities over 550 miles of a modern waterway, 12 feet minimum deep in the lower 216 miles and with a 9-foot minimum depth in the reach above.

TABLE 15. - ESTIMATED COST, STARTING JULY 1, 1965, OF THE COMPREHENSIVE DEVELOPMENT PROGRAM FOR NAVIGATION TO 2020

Project	Million dollars		
	Total by 1980	Total by 2000	Total by 2020
All waterways in study area[1]	1,253	2,375	2,591
Further improvement of existing waterways[1]	1,253	1,445	1,461
1. Ohio River[2]	993	1,043	1,043
(a) Lock and dam replacement plan completion[2]	993	993	993
(b) Channel deepening	-	50	50
2. Monongahela River[3]	143	163	173
(a) Lock and dam replacement plan completion[3]	143	143	143
(b) Channel deepening	-	20	30
3. Kanawha River	90	110	110
(a) Lock and dam replacement	90	90	90
(b) Channel deepening	-	20	20
4. Cumberland River[4]	27	32	38
(a) Lock and dam replacement program completion[4]	13	13	13
(b) Waterway extension (Celina lock and dam and Wolf Creek Dam cargo lift)	14	14	14
(c) Channel deepening to Old Hickory Dam	-	5	11
5. Green and Barren Rivers	-	17	17
(a) Lock and dam replacement in upper waterway section	-	15	15
(b) Channel deepening in lower Green River	-	2	2
6. Lower Allegheny River	-	80	80
(a) Lock and dam replacement	-	70	70
(b) Channel deepening	-	10	10
New waterways	-	930	1,130
1. Lake Erie-Ohio River Canal	-	690	690
2. Big Sandy River-Levisa Fork Waterway	-	-	200
3. Lower Wabash River Waterway	-	240	240

[1] Includes $785 million for completing projects in going programs.
[2] Includes $753 million for completing projects in going program.
[3] Includes $19 million for completing projects in going program.
[4] Includes $13 million for completing projects in going program.

NOTE. - 1. Cost shown is that allocated to the navigation function of projects or portions of projects located in the study area.
2. Location of the projects, identified by their number in this table, is shown in figure 25.


LAKE MICHIGAN
LAKE ERIE
CHICAGO
TOLEDO
CLEVELAND
LAKE ERIE-OHIO RIVER CANAL
N.Y.
PA.
MONTGOMERY ISLAND
DASHIELDS
EMSWORTH
PITTSBURGH
ALLEGHENY R
WHEELING
MONONGAHELA R
MD.
ILL.
IND.
OHIO
W. VA.
KY.
VA.
TENN.
N.C.
MISS.
ALA.
GA.
ILLINOIS WATERWAY
WABASH R
TIPPECANOE R
INDIANAPOLIS
TERRE HAUTE
WHITE R
COLUMBUS
SCIOTO R
MUSKINGUM R
PARKERSBURG
L. KANAWHA R
WEST FORK R
TYGART R
GREAT MIAMI R
LITTLE MIAMI R
CINCINNATI
RIVER
GALLIPOLIS
KANAWHA R
WINFIELD
CHARLESTON
MARMET
LONDON
LICKING R
BIG SANDY
LEVISA FK
TUG FK
OHIO
LOUISVILLE
KENTUCKY R
FRANKFORT
EVANSVILLE
SALINE R
GREEN RIVER
BARREN R
MISS R
MISSOURI R
ST LOUIS
KASKASKIA R
MISSISSIPPI RIVER
CAIRO
CUMBERLAND R
NASHVILLE
EMORY R
KNOXVILLE
HOLSTON R
CLINCH R
FRENCH BROAD R
HIWASSEE R
CHATTANOOGA
TENNESSEE RIVER
TENNESSEE-TOMBIGBEE WATERWAY
N
10 0 10 20 30 40 50 60 70 80 90 100
SCALE IN MILES
LEGEND
OHIO RIVER BASIN STUDY AREA
WATERWAYS IN 1965 PROGRAM
POTENTIAL EXTENSIONS AND NEW WATERWAYS
POTENTIAL INTERREGIONAL WATERWAYS NOT IN BASIN PROGRAM
IMPROVEMENTS TO EXISTING WATERWAYS BEYOND PROJECTS IN 1965 PROGRAM
NEW WATERWAYS
NAVIGATION STRUCTURE TO BE REPLACED OR MODERNIZED
NOTE.— For key to elements in development plan, see table 15.
OHIO RIVER BASIN COMPREHENSIVE SURVEY
DEVELOPMENT PLAN FOR FREIGHT-MOVING NAVIGATION
CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX L FIGURE 25

ANNEX A

METHODOLOGY OF PROJECTING ANNUAL GROSS DEMANDS FOR COMMODITY MOVEMENT ON THE EXISTING WATERWAYS SYSTEM

Projections of annual freight movement on the waterways system were for the most part based on indices of projected demands, by subareas,[1] for each of five general commodity groups. Estimates of future water carriage of goods in these groups were derived in the following four major steps:

1. Calculating future levels of subarea and extraregional demands for major commodity groups susceptible to water movement on Ohio Basin streams, i.e., coal and coke; crude petroleum and products; chemicals and sulfur; iron and steel; and stone, sand, and gravel. These represented the bulk of existing waterborne commerce, and pertinent statistics were readily available.

2. Establishing, for the selected commodities, the current water traffic patterns in tons by areas of origin and destination.

3. Applying the appropriate future demand indices to the historical area-to-area shipments in order to project waterway tonnages.

4. Approximating future ton-miles on the basis of projected tonnages and generalizations concerning average lengths of haul.

A sixth commodity category, "Unclassified," encompassed all goods moved over Ohio Basin waterways and not elsewhere classified, and their future waterway tonnage was estimated by methods described later. Ton-miles for this category were projected in the same way as for the other five groups.

The next paragraphs contain a discussion of the four above-listed steps.

1. Levels of demands

a. Basin subareas. - The following deliniates the procedure for estimating future subarea levels of demand for the selected bulk commodities.

(1) Industrial demand. - The demand by industry in the subareas was analyzed. For each selected commodity, the total subarea industrial demand was estimated as the summation of the demands of individual industries. Each of these was obtained by multiplying the projected subarea industry output (expressed in constant 1960 dollars) by the respective

[1] Economic data for the 19 subareas of the Ohio River Basin are presented in "Appendix B: Projective Economic Study." A map of the areas is attached at the back of that appendix.

input coefficient. Projected industry outputs for the basin's subareas were given in "Appendix B: Projective Economic Study." Industrial input coefficients for the United States were published in "Survey of Current Business," November 1964 and September 1965. The coefficients stated the dollar fraction value of an industry's output required to produce one dollar of gross output of another industry. For example, to produce one dollar value of petroleum refining output, an input of about $0.52 worth of crude oil was required.

The available U.S. input coefficients were for 83 different industry groups, while the subarea industrial output projections were given for 24 general industry groups. (Both groupings were related to the codes in the "Standard Industrial Classification Manual," Bureau of the Budget, 1957.) Hence, it was necessary to modify the coefficients for application to the more general, 24-sector, subarea industry groupings. An example of how this was accomplished follows.

The U.S. input coefficients indicating the demand for coal by the primary metals industry were: .02615 for primary iron and steel manufacturing; and .00121 for primary nonferrous metals manufacturing. For the basin subareas, dollar output was given for primary metals as a whole only; therefore, an input coefficient reflecting the combined coal demand by both iron and steel and nonferrous metals manufacturing was necessary. Such a coefficient was approximated by using the percent of current subarea employment in primary ferrous and nonferrous manufacturing to weight the two separate national coefficients. "County Business Patterns, 1962," U.S. Dept. of Commerce, was used for detailed industry employment data.

A similar operation was carried out for each subarea industry group to obtain weighted input coefficients for the industries using the selected waterborne commodities. After approximating the 24 industry input coefficients, total subarea industrial demand was computed by multiplying each industry output for 1960 and future years by the respective coefficient and summing the products.

The 1960 and projected subarea demands for a commodity were expressed in 1960 dollars. Where possible, the dollar demands were converted to tons by using an average 1960 basin dollar value per ton. This was done to check the reasonableness of the various subareas' demands for the physical amounts implied by the dollar projections. Adjustments were made if historical data on pertinent production and consumption indicated discrepancies.

The check, for example, made it apparent that coal usage by Ohio River Basin steamelectric plants would not be adequately accounted for with national input coefficients applied to subarea dollar output projections for the transportation, communication, and utilities industry group. This was due to the low cost of coal delivered to the large number of coal-fired steamelectric plants in the basin. Subarea coal demands for the electric power industry were projected by using the indices of projected subarea net

electric generation given in "Appendix B: Projective Economic Study." (Projections to 1980, of electric generating capacity, by tributary drainage basins, were given in the Federal Power Commission's "Appendix I: Electric Power Resources and Requirements in the Ohio River Basin." These projections appeared to be generally in accord with corresponding net electric generation estimates in "Appendix B: Projective Economic Study" after accounting for some area boundary differences in the two studies. Coal usage projections, based on either study, would not differ significantly.)

The effect on future coal demand of using nuclear power for electric generation was considered. The conclusions reached in appendices B and I, indicated that nuclear power in the Ohio Basin would make the greatest inroads in electric generation in areas farthest away from coal fields. In the light of this, it seemed likely that subareas now receiving water-delivered coal for steamelectric plants would continue to do so in the future. In these subareas, coal-fired, steam-electric plants would probably remain the most economical means of electric generation due to the proximity of coal fields and the availability of low-cost water transport. Projected demands for steamelectric coal in the subareas with a canalized waterway were therefore based on projected electric generation after adjustment for increased efficiencies in coal use at steamelectric plants.

The second-largest user of coal in the basin is the steel industry. In projecting its demand, metallurgical coal input coefficients were adjusted to reflect expected changes in steel production technology.

(2) Household demand. - The demands for the selected bulk commodities by the household sector in the various subareas were found to be negligible, except for petroleum products. Demands for petroleum products were approximated by multiplying the projected per capita household consumption by the projected population in each subarea. Pertinent data from "Appendix B: Projective Economic Study" were used.

b. Extrabasin regions. - The demand in outside regions for study area products was based on the origin areas' output projections with the assumption that the level of exports would remain a constant share of output. Output data presented in "Appendix B: Projective Economic Study" were used for all products except coal. For the latter, origin area production was derived from the total basin coal output projected in Attachment B: Mineral Resource and Mining to "Appendix K: Development Program Formulation" by distributing that output to the subareas in accord with the respective percentage shares given in the "Projective Economic Study."

c. Accuracy of estimating procedure. - There were many approximations in the foregoing proposition. A major one was attributable to the static nature of the input-output coefficients, which represented the national average at one point in time. Another was due to the disregard, except in the case of coal usage by the steel and power industries, of probable future changes in input composition. Also, in adjusting the national coefficients to fit individual subareas, modifying factors, such as economies

of scale, were necessarily overlooked. By using subarea employment distribution to weight the coefficients, the assumptions were made that productivity among the related industry groups was equal and the industrial mix within the general groups was static.

The method was considered to provide an approximation of subarea demands for the selected bulk commodities, of sufficient accuracy to indicate probable future waterborne movements of those products.

2. Water traffic patterns

The major source for current water traffic patterns was the annual Corps of Engineers publication, "Waterborne Commerce of the United States, Domestic Inland Traffic: Areas of Origin and Destination of Principal Commodities, Supplement I to Part 5: National Summaries." It contained historical area-to-area water movement for the following of the selected commodities: coal, petroleum and products, iron and steel, and chemicals. Tables 2 through 9 in this appendix show in substance how these statistics were organized. The traffic pattern for stone, sand, and gravel was determined from other statistics. Such tonnage flow information for 1960, together with accounts on detailed point-to-point water shipments, was the base to which projection indices were applied.

3. Projecting waterway tonnages

The methods of projecting Ohio River and tributary waterborne volumes were similar; in both, indices of future subarea demands were applied to 1960 base year traffic. For any commodity, the demands in subareas which contained an Ohio main stem reach or a navigable tributary, were assumed to reflect the market for waterborne volumes. However, if information indicated that significant amounts were shipped exriver beyond the subareas contiguous to the waterway system, appropriate subarea indices reflecting the changes in the ultimate receivers' demands were incorporated in the analysis. Thus, import and intrabasin commerce in the selected commodities was projected generally by multiplying the 1960 waterborne tonnages terminated in each of the basin's navigable reaches, by indices of future demand in the appropriate subarea(s). Projected waterborne export traffic was based on changes in supply (output) levels.

Growth rates of waterborne movements determined by projected levels of demands were modified where considered desirable. For example, the rate of change to 1970 for waterborne chemicals was adjusted higher than that indicated for the projected chemicals demand or output as chemicals water transport has been growing faster than the demand for the commodity. Another adjustment reflecting the projected effects of mine-mouth electric generation plants resulted in projected waterborne coal tonnages smaller than those indicated by the future demand for coal.

Future commodity movements by water determined by use demand levels for those commodities and by established traffic patterns as discussed

previously required that reserves and supplies susceptible to water movement be adequate to meet all increased demands. An examination of supplies of the selected commodities indicated they were adequate to meet the projected demand and waterway traffic.

a. Ohio River freight movement. - Individual commodity group projections were made, and their summation gave the total traffic. The 1960 volume on the Ohio of each major commodity group, except the category "Unclassified," was divided into tonnages terminated in each of the three main stem reaches and the tributaries, and in extrabasin waterways. These tonnages were then multiplied by the commodity demand index for the appropriate subareas and the extrabasin region. The projected shipments to each area were summed and yielded for each commodity the total projected movement on the Ohio.

Tonnage in the category "Unclassified" was projected independently of the above method. Future volumes of this commodity group were derived by a time series analysis of the trend in the period 1952-64 and checked by projections based on an index of projected total Ohio River Basin gross output of all industries.

Future Ohio River tonnage, by commodity groups, as well as their summation giving total traffic volumes, are presented in table 10, this appendix.

b. Freight movements on the major improved tributaries. - For the tributaries, only overall future tonnages were derived, based on demand indices for the most important commodities which the streams currently carried. For the Green River, for example, total traffic was projected by using the index for coal movement only, since coal accounted for 99 percent of the river's commerce. For the Kanawha, coal, chemicals, petroleum products, and stone, sand, and gravel, which accounted for over 95 percent of the 1960 base year traffic, were considered in deriving the indices for total projected movements.

4. Projecting waterway ton-miles

In general, future ton-mile estimates for the basin's waterways were based on the tonnage projections. But the procedure followed for the Ohio River differed from that for the tributaries.

a. Ohio River. - Ton-miles were first projected for each commodity group. As an initial step, future average hauls for the various commodity groups were estimated by means of time series trend projections. The projected average hauls were then multiplied by the corresponding tonnage projections. The summation of these ton-mile estimates gave the total future ton-miles expected for the Ohio River. Table 10, this appendix, contains the estimated future ton-miles, both total and by commodities.

b. Major improved tributaries. - The latest available (1964) average length of haul for all commodities moving on the individual waterways was

multiplied by the projected total tonnage. The result was the total ton-miles expected in the future on each waterway. Table II in this appendix shows the projected ton-miles for the major tributaries in the study area.